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CONTENTS

Page

The relation of resource management to research 1

Watershed management and protection 2
    Watershed protection requirements 2
    Watershed restoration 7
    Water conservation 9
    Program for 1952 10

Range management research 12
    Big game-livestock range 12
    Winter range 18
    Spring-fall range 20
    Enclosure studies in Nevada 23
    Program for 1952 24

Research in range reseeding 26
    Species adaptability 26
    Methods of removing competition 37
    Grazing trials on reseeded range 38
    Plant breeding 44
    Problems in halogeton control 44
    Program for 1952 48

Economics 50
    Range economics 50
    Forest survey 53

Forest management research 54
    Seed viability 55
    Program for 1952 55

Flood control surveys 56
    Progress on surveys 56
    Local floods 60
    Colorado River basin 61
    Other activities 62

Publications 63

THE RELATION OF RESOURCE MANAGEMENT AND RESEARCH

Managers of public forest and range lands must cope with many complex questions in providing for use of the resources of these lands while insuring their continued productivity. The magnitude of the job may be indicated by framing a few of the questions with which they must deal.

How much ground cover (vegetation and plant litter) is needed on our watersheds to prevent accelerated erosion and control storm runoff? What is the long-term effect on plant cover and soil mantle of various intensities of grazing use? What kinds of depleted range areas can be successfully reseeded and with what species of plants? Are domestic livestock and game animals serious competitors for available forage? What timber harvesting practices are best for sustaining and improving the forest lands of this region? What economic and social factors should be considered in determining the best use of an area of land?

Even a cursory examination of the above list of questions will indicate the many technical and scientific disciplines that must be drawn on for answers. These include the fields of botany, ecology, soil science, zoology, climatology, hydrology, silviculture, and economics. The problems are rarely simple, but often have a complex relation to other, seemingly unrelated, problems.

To determine proper levels of livestock grazing, for example, requires knowledge of the amount of ground cover needed to prevent soil erosion. It also requires knowledge of the effect grazing has on ground cover. Furthermore, grazing capacity varies from locality to locality as the relation changes between grazing use, ground cover, and erosion. A problem such as this, the determination of the maximum amount of grazing that is possible without jeopardizing the productive and hydrologic functions of the soil resource, clearly requires technical information from the physical and biological sciences. Nor is this all. Changes in stocking rates to maintain range productivity inevitably have a social and economic impact that needs to be carefully evaluated.

The two groups most immediately concerned with the problems of forest and range management are resource users and land administrators. Both have a public responsibility to maintain, or if possible to increase, the productivity of public forest and range lands. What is the basis upon which both groups may best reach sound, comprehensive decisions that are in the public interest?

A high level of resource productivity can be maintained only if resource users and administrative officials act on the basis of scientific findings with regard to each problem. Resource productivity cannot be safeguarded if decisions are based on anything less. The necessary scientific findings are the products of research in the locality and under the conditions to which the facts are to be applied. The research program of the Intermountain Forest and Range Experiment Station is directed to the discovery of facts that will contribute to the solution of these problems, as the following divisional reports indicate.

WATERSHED MANAGEMENT AND PROTECTION

During the past year, significant progress was made in the search for ways to achieve more satisfactory watershed conditions on the forest and range lands of the Intermountain region. Through a variety of study methods, new information was obtained about the specific plant cover and soil conditions that are required on sloping lands for keeping soil in place and for controlling dangerous storm runoff. Further information was also obtained on the problem of how to restore satisfactory watershed conditions on depleted and eroding flood source areas. Studies of snow accumulation and melting and of evapo-transpiration losses shed new light on the problem of water conservation. Highlights of these findings are here reported together with plans for 1952.

WATERSHED PROTECTION REQUIREMENTS

All of the lands in the Intermountain region are subject to occasional but inevitable, high-intensity summer rainfall. The water from these dashing rains that is not absorbed by the soil mantle when it falls produces overland flow. This is a dangerous type of runoff. It is a powerful eroding agent and can generate violent discharges capable of scouring channels and of causing serious flood and sedimentation damage downstream. Moreover, once a rill and gully system has been carved into the soil it takes less and less rainfall to produce increasingly larger flood discharges and heavier sediment loads. The more efficient drainage systems thus created also quicken the release of seepage flow during snow melt.

The solution to the problem of controlling storm runoff and accelerated erosion lies in the maintenance of plant cover and soil conditions that will favor the absorption of water from torrential rains and melted snow where it falls on the land. But what are the specific conditions of plant cover and soil that are needed for this purpose?

Answers to this question have been sought in several ways. One approach involved the measurement of runoff and erosion from paired watersheds over a long period of years during which time the plant cover was altered by grazing. Another approach involved the same kind of measurements from small, permanent runoff plots on which the plant cover was altered by cutting, burning, and artificial reseeding. A third approach involved the application of artificial rainfall to small plots by means of an infiltrometer and the determination of the relations between the runoff and erosion behavior of the plots and their plant cover characteristics. The tests to date reveal some strikingly similar relationships.

Area A and B Experimental watersheds.--Last year was the 35th year of record taking on the two 10-acre experimental watersheds along the crest of the Wasatch Plateau near Ephraim, Utah. The current year's records, when considered with those obtained from the many hundreds of storm events in the previous years provides a factual basis for understanding the protection requirements of subalpine-herbaceous range in south-central Utah.

When this experiment began in 1916, Area A was in seriously depleted condition. Only about 20 percent of the ground surface was covered by plants and litter, and a large percentage of the plants were annual weed species of little value as forage. Through protection from grazing and a small amount of reseeding and shrub planting, the amount of plant and litter cover increased rather rapidly for a few years to a level of about 40 percent. Since this initial surge, the increase in ground cover has been slow. At the present time the over-all average ground cover is about 55 percent, though spots remain on which there is less than 30 percent ground cover. In this period there has been a decline in annual weed species and an increase in perennial grasses and broad leaf forbs.

Area B, in 1916 was in fair condition. It had a plant and litter cover of about 40 percent. This condition was maintained for a number of years by conservative grazing. Between 1935 and 1940 Area B was deliberately overgrazed to deplete the plant cover. During World War II, this treatment was stopped. It was again resumed in 1946 and has been continued through 1951. As a result of this abusive use, the plant and litter cover has been reduced to 20 percent, the same as that on Area A at the beginning of the study.

These changes in the plant and litter cover have caused drastic changes in the relative runoff and erosion behavior of the two areas. During the first several years of the experiment, summer storm runoff was 3.4 times greater on Area A than Area B. During the last five years, Area B yielded four times more than Area A. Annual sediment production from Area A at first averaged about 3.5 times greater than Area B whereas now, Area B is producing 9.4 times more than Area A. The change in control of erosion during summer storms is even more striking. The early A/B sediment production ratio was 3.8 to 1.0 whereas it is now 1 to 44. When it is considered that both areas received essentially the same amount of winter snow and summer rain, the reversal in their capacity to control runoff and erosion is unquestionably due to the changes in the kind and amount of plant cover and surface soil conditions as a result of protection from grazing on the one hand and severe overgrazing on the other.

During the course of the study, annual sediment production has averaged on the order of 0.1 to 1.0 acre-foot per square mile of watershed on Area B. These are excessively rapid erosion rates and clearly indicate that a ground cover of 20 to 40 percent is inadequate for watershed protection purposes.

On Area A the average annual sediment production rate was about 3.0 acre feet per square mile when the ground cover averaged 20 percent. In recent years, with a ground cover of 55 percent, the rate has dropped to about 0.05 acre-foot per square mile. This represents a very substantial reduction in soil loss but is not the ultimate degree of stability that can and should be achieved. This area still has numerous raw gullies and other inadequately covered spots which remain as runoff and sediment sources. Though an increase in the over-all average ground cover from 20 to 55 percent has brought about a major improvement in runoff and erosion control, it is evident that satisfactory conditions will not prevail until more of the ground is covered by plants and litter on all parts of the watershed.

The 1951 records from the A and B experimental watersheds are now undergoing final analysis. These data are to be added to the earlier records as a basis for a comprehensive report on the entire period of study.

Parrish Runoff Plots.--In 1936 a group of 16 1/40- and 1/10-acre runoff plots was installed in the headwaters of the Parrish Creek Watershed near Farmington, Utah. Some of these plots were located on depleted aspen-herbaceous sites typical of those from which storm runoff had originated to start the destructive mud-rock floods of 1930. Others were located on less depleted sites which bore no signs of excessive runoff or accelerated erosion. In 1947, the plant cover on some of the nonflood source areas was removed by cutting and burning. In the same year, some of the depleted flood-source areas were seeded to grass and were mulched. Others were allowed to change naturally. During the entire period records were made of changes in the amount of plant and litter cover, of the amount and rate of summer rainfall, and of the amount of storm runoff and eroded soil. Analysis of the records for the period 1936 to 1950 brought out how much plant and litter cover is required for effective control of storm runoff on the aspen-herbaceous range lands of this locality.

In one analysis, a total of 216 records were used to develop a relation between soil loss and rainfall runoff. This relation showed erosion to be negligible when 95 percent or more of the rainfall was absorbed by the mantle. On the other hand, soil losses increased sharply when runoff exceeded 5 percent of each storm. Because stable soil is a primary requisite in land management, 5-percent storm runoff appears to be the maximum allowable for watershed protection purposes on this type of land.

In a second analysis the amount of storm runoff was related to the amount of ground cover. This analysis revealed that during minor storms--those in which maximum rainfall rates are less than 1.50 inches per hour for 5 minutes--a ground cover of only 5 percent was required to keep storm runoff to less than the assumed allowable 5 percent maximum. Moderate storms including those in which maximum rainfall rates ranged between 1.50 and 3.00 inches per hour for 5 minutes, required a ground cover of 40 percent to control runoff to the 5 percent level. In major storms, with maximum rainfall rates in excess of 3.00 inches per hour, a 65-percent ground cover was required to control runoff. There were four such storms in the period of record, indicating they can be expected on the average of once every four or five years in this locality. This relatively high frequency for very torrential summer rains clearly indicates the need for maintaining at least a two-thirds ground cover during the summer rain season. This protection requirement agrees closely with the apparent needs on the subalpine range in central Utah. A detailed report on this study has been accepted for publication in the Journal of Forestry.

Infiltrometer Study on Uinta National Forest.--During the past fall, records of infiltration, runoff, and erosion were obtained by means of an infiltrometer (type FA) at several locations on the Uinta National Forest. The tests were made on grazed range and on areas inside of grazing exclosures. Some of the latter had only recently been fenced. Nevertheless, total ground averaged 73 percent on the test plots inside the exclosures and only 47 percent on the outside grazed range. Artificial rainfall was first applied when the soils were relatively dry. These applications were repeated 24 hours later to simulate prewet soil conditions as sometimes occurs when a second storm follows an initial rain. Analyses were made of the infiltration rate, amount of runoff, and amount of soil loss at the end of the first 0.5 inch and 1.0 inch of applied rainfall and also at the end of 36 minutes of rainfall. The latter volume averaged about 2.25 inches.

Infiltration rates averaged from 5 to 50 percent lower on the grazed sites than on the ungrazed areas. Storm runoff from the grazed plots ranged from 50 to 100 percent more than on the ungrazed areas. Soil losses on the grazed areas averaged 6 to 8 times more than on the ungrazed areas.

Further analyses revealed a distinctly curved inverse relation between the amounts of sediment eroded and amounts of ground cover. The flex point in these curves between no or relatively small amounts of erosion and increasingly greater amounts of soil loss varied with the amount of ground cover depending upon both the amount of rainfall considered and the antecedent soil moisture conditions. A 60- to 70-percent ground cover was effective in controlling erosion under the impact of a 2.25-inch rain when the soil was relatively dry but an 80- to 90-percent ground cover was needed to achieve the same degree of soil stability when the mantle was wet. Decreasingly less amounts of ground cover were effective in holding soil losses to low amounts under the impact of 1.0- and 0.50-inch rainfall.

The data from these tests, with the exception of the most severe test on prewet soil, are in close agreement with the findings from the Parrish Plots and substantiate the need for keeping at least two-thirds of the ground covered by plants and litter in order to control storm runoff and erosion.

Trampling Disturbance Study.--Last year a further step was taken in an endeavor to determine the plant cover conditions that are necessary to minimize storm runoff and erosion on the steeply sloping grassland range of the Boise River Watershed in Idaho. In previous tests with infiltrometers, it was found that a 70-percent ground cover, including a 35- to 45-percent plant cover, with bare soil openings no greater than 4 inches in diameter were needed to minimize storm runoff and erosion of the coarse granitic soil on currently ungrazed or otherwise undisturbed wheatgrass range. The same amount of ground cover but a maximum bare soil opening of 2 inches was required on undisturbed cheargrass range.

Last summer areas of wheatgrass and cheatgrass range were subjected to artificial trampling disturbance. The amount of the trampling was varied so as to disturb 0, 10, 20, 40, and 60 percent of the ground surface. These disturbance conditions were made on ranges having initial ground covers of 70 to 75 percent, 80 to 85 percent, and 90 to 95 percent. All plots, including 5 replications of each condition, were then subjected to 1.80 inches of artificial rainfall by means of a type F infiltrometer and records obtained of runoff and soil loss.

Trampling disturbance decreased the amount of ground cover in all cases. The amount of the reduction in ground cover ranged from 5 percent under the impact of 10-percent trampling disturbance to 25 percent when as much as 60 percent of the soil surface was disturbed.

Trampling disturbance also increased the size of the bare soil openings between plants and litter. The diameter of these openings was increased from about 1 to as much as 7 inches on the wheatgrass range depending upon the degree of trampling disturbance. On cheatgrass range, openings were increased in size by from 1 to 9 inches.

On both wheatgrass and cheatgrass range having an initial plant and litter cover of 70 to 75 percent, a 10-percent trampling disturbance did not appreciably step up runoff or erosion above amounts on comparable undisturbed sites. When subjected to 20 percent or more disturbance, however, the amounts of runoff and erosion were at least doubled over those from undisturbed range. This suggests that on ranges having an initial ground cover of 70- to 75-percent grazing use should be so regulated as to not disturb more than 10 percent of the ground surface by trampling.

A 20-percent trampling disturbance was the maximum allowable on ranges having an initial ground cover to 80 to 85 percent. Ranges having an initial ground cover of 90 to 95 percent were able to control runoff and erosion to about the same degree as undisturbed range, even when subjected to a 60-percent trampling disturbance.

The tests to date show that essentially similar ground cover conditions are needed for protection purposes on ungrazed granitic soil-grassland ranges of southwestern Idaho as on other types of mountainous summer range in Utah. They also indicate that where the ground cover is currently reduced and bare soil openings are enlarged by trampling disturbance such as can be expected on grazed range, management should set a pregrazing disturbance goal of more than a two-thirds ground cover in order that the soil surface will be adequately covered after the grazing disturbance.

Two reports on the effects of ground cover and size of bare soil openings upon runoff and erosion from the grassland range of the Boise River Watershed were published last year. The effects of trampling disturbance will be reported in the coming year. It is also planned to make an observational study of the changes in ground cover and size of bare soil openings that occur on the range under the influence of given amounts of livestock grazing by sheep and cattle. These observations will be compared with the infiltrometer plot findings to establish grazing use standards in keeping with watershed protection requirements.

WATERSHED RESTORATION

Extensive portions of both the humid mountain lands and the more arid foothill, bench, and valley lands in this region are known to be in unsatisfactory watershed condition as a result of abusive use of the plant cover and soil. Considerable progress has been made in developing effective methods of restoring these eroding and depleted areas where soil and moisture conditions are favorable for plant growth. Restoration of satisfactory watershed conditions on seriously deteriorated sites, however, continues to be a problem because effective methods have not been found for getting new plants started and for keeping them alive on such sites. During the past summer further evidence was obtained of the effectiveness of intensive watershed improvement measures on humid mountain lands and of the obstacles that stand in the way of restoring satisfactory watershed conditions on lands where poor soils inhibit the survival of perennial plant seedlings.

Improved watersheds withstand torrential rain.--Last summer for the fifth time in 15 years, a torrential rain failed to produce a mud-rock flood from former flood-producing areas on the Wasatch Experimental Watersheds. The storm occurred on August 19. The most torrential portion centered over several watersheds (Rice, Miller, Steed, Ford, and Parrish) where flood-source areas have been improved by contour trenches, grass seeding, and protection from livestock grazing and fire. Over these areas, the amount of rainfall varied from 0.85 to 1.23 inches and maximum rates for 5 minutes varied from 2.88 to 4.80 inches per hour. An adjacent area (Halfway) having unsatisfactory watershed conditions, produced a mud-rock flood in 1947 when it was subjected to a rain of 0.79 inch and a maximum rate of 4.90 inches per hour.

That the torrential rain of August 19 failed to generate a flood is understandable. Runoff plot records during this storm show that denuded plots with very sparse plant cover comparable to conditions on the flood-source areas prior to their treatment, yielded from 35- to 53-percent rainfall runoff as overland flow. This storm runoff carried away from 140 to 280 cubic feet of soil per acre. However, virtually all of the original flood-source areas now have a plant and litter cover that affords protection to at least 75 percent of the soil surface. Records from runoff plots representative of these conditions during the July 19 storm show they produced only 0.5 to 1.0 percent storm runoff and lost no soil.

Seedling survival study.--In the fall of 1950, stiffhair wheatgrass was seeded on a number of steep, south-facing slopes of the depleted and eroding granitic soil-grassland range of the Boise River Watershed. Counts made in the spring of 1951 showed very good germination and initial start of seedling plants. Subsequent observations were made of seedling survival. In addition, observations were made of the depth of roots on both live and dead plants and the depth to which the soil had dried to the wilting point.

On sites where native bunchgrasses had been left as competition, all stiffhair seedlings apparently died by September 20. On sites where competition has been eliminated, a few seedlings of stiffhair wheatgrass remained alive. On these sites it was noted that the roots of the live plants extended a few inches deeper than the depth of the soil-moisture wilting point whereas the roots of the dead plants were a few inches shorter (table 1). These observations confirm a long-held belief that soil moisture is a potent limiting factor affecting the survival of perennial grasses on the coarse, droughty soils of the Boise River Watershed. They also show the need for finding a perennial plant with either very rapid root growth habits or capacity to survive through a long dormant period in the summer and fall.

Table 1.--Average maximum depth of root growth, depth of soil moisture wilting percentage, and mortality of stiffhair wheatgrass seedlings on weeded granitic soil range

Date	Root depth[1/] Live plants	Root depth[1/] Dead plants	Depth of wilting percentage	Seedling mortality
	Inches	Inches	Inches	Percent
7/10	18	14	16	31
7/23	20	17	18	51
8/6	24	19	20	63
8/17	28	21	25	73
8/31	29	22	26	80
9/20	30	27	30	95

[1/] Average maximum from 10 live and dead plants on each date.

WATER CONSERVATION

The supply of usable water in the Intermountain region is naturally limited because only one-fifth of the lands receive enough precipitation to yield perennial stream flow. These are the high-elevation foothills, plateaus, and mountains. These lands on the average receive from 16 to 60 inches of precipitation annually. They also lose 15 to 20 inches of water annually by evapo-transpiration processes. Net seepage flow water yields therefore range from less than 1 inch on the drier portions to as much as 35 and 40 inches on the more humid headwater areas.

The usable supply of water is also limited because most of the runoff occurs in the spring and early summer during the snow melt period, at a time when it cannot all be used. Storage of the surplus spring runoff in reservoirs is one method of conserving water for later use. However, evaporation takes a substantial portion of this stored water.

The usability of water from the mountain lands can also be impaired when runoff occurs as sediment-laden overland flow. Though this type of runoff usually does not amount to more than 1 or 2 percent of the annual runoff it has far-reaching adverse effects on the water supply. It is generally unfit for direct use. It can cause great direct flood damage. Moreover, by carrying sediment into water conveyance and storage structures it reduces their capacity to conserve and deliver subsequent yields of runoff. An economy developed on the basis of stored water obviously cannot survive when the storage facilities are destroyed.

Watershed management can aid in the conservation of water. It can do so by maintaining plant cover and soil conditions that minimize the occurrence of undesirable overland flow and sedimentation, that increase the amount of snow that reaches the ground and delay its melt, and that reduce evapo-transpiration losses during the growing season. Of these possibilities, the control of stormflow runoff and erosion is of first importance because steep mountain lands are highly susceptible to impairment of their capacity to take in water and to resist accelerated erosion. Studies of the watershed protection requirements to date show that at least two-thirds of the ground surface should be covered by plants and litter for this purpose. Because of the urgent need for information on watershed protection requirements, relatively more research effort has been devoted to that phase of the water conservation problem than to other approaches. Last year, however, additional information was obtained on snow accumulation and melting and upon the evapo-transpiration losses from some range lands.

Snow accumulation and melting.--Last year, an analysis was made of three years' of snow accumulation and melting records that had been taken on some steeply sloping ponderosa pine lands in the Boise River Watershed. These data showed north-facing slopes to be more effective than slopes on other aspects for accumulating snow during the winter season and for retaining it during the spring. Large brush openings on north aspects provided the best snow storage sites, though small brush openings and areas with sapling pine stands were almost as effective. On south aspects, large brush openings are to be avoided whereas clumps of saplings and small openings shaded by large trees are most desirable. A detailed report of these findings was published in the Journal of Forestry.

Water consumption by poor and good forage.--Last year, information was obtained on the water consumption losses from two types of range in two localities within the region. In the one case, a comparison was made between sites having a thin stand of annual weeds (mostly kitchenweed, Chinese lettuce, and knotweed) and a dense stand of crested wheatgrass, based on records taken on the spring-fall range of the Boise River Watershed. In the other case, records were taken on the Wasatch Experimental Watersheds on sites having a dense stand of mixed perennial bunchgrasses and on sites having a thin stand of annual weeds, including mostly tarweed and knotweed.

The year-long consumptive use of water on the Boise foothill range was found to be 18.16 inches for the annual weed sites and 19.81 inches for the crested wheatgrass sites. On the more elevated and humid Wasatch Mountain area, the summer season consumptive losses amounted to 14.65 inches on the grass sites and 13.36 on the annual weed sites. These data indicate the annual weed sites will yield 1.29 to 1.65 inches more water as seepage flow during the spring runoff period than will the densely covered grassland areas. There are, however, other consequences to be considered. For one, it has been well established that stands of annual weeds are very ineffective for controlling dangerous stormflow runoff and for preventing accelerated erosion. Moreover, a crop of virtually worthless annual weeds dissipates from 13 to 18 inches of water. The grassland areas, at a cost of less than 10 percent more water, provide a valuable forage crop as well as protection against floods and sedimentation.

The possibility of developing a plant cover that will provide effective control of storm runoff and erosion and at the same time consume a minimum of water remains as a challenge to research. The solution appears to lie in plants that will cover the ground surface rather completely and at least uniformly but which will extract water from the mantle to only shallow depths. It is planned to extend research in this direction in the coming year.

PROGRAM FOR 1952

Effort in watershed studies during the coming year at three of the research centers will be divided about equally between the preparation of reports, analysis of accumulated data, and the extension of several studies.

Boise Research Center.--Reports will be prepared on: (1) the trampling disturbance study; (2) the evapo-transpiration study; and (3) the seedling survival-soil moisture study. A study will be made of the effects of livestock grazing on the watershed protection requirements of spring-fall range and plans will be completed for a logging-sediment production study on ponderosa pine lands.

Wasatch Research Center.--A report will be prepared on the highlights of watershed management for Region 4 for in-Service use. A proposal will also be completed for establishing a Wasatch Experimental Forest. Streamflow, runoff plots, and climatic records will be brought up to date and analyzed with a view toward the planning of specific watershed studies. Plans will be developed for refining and extending the study of evapo-transpiration losses on summer range areas.

Great Basin Research Center.--The major effort here will be preparation of a comprehensive report on the Area A and B Watersheds. In addition, analysis will be made of the runoff records from two other high-elevation watersheds to determine their usefulness for a detailed study of runoff control and water yield. Plans will also be developed for a study of water consumption losses on range lands in several precipitation zones.

RANGE MANAGEMENT RESEARCH

Most of the phases of the program for range management research outlined in last year's annual report were completed in 1951. Several manuscripts embodying research results have been brought to final stages of preparation or published.

"Indicators of condition and trend on high range-watersheds of the Intermountain region" was issued as Agriculture Handbook No. 19 during the year. "Subalpine vegetation of the Wasatch Plateau, Utah" will be completed and submitted for publication in a technical journal during 1952, as will "Ecological effects of planned burning of sagebrush-grass range on the upper Snake River Plains." The latter is intended as a Technical Bulletin. Revision of the manuscript, "Management of winter sheep ranges of the Intermountain region," should be completed early in the year.

The report on the pocket gopher study plots, "Influence of pocket gophers on vegetation of subalpine grassland in central Utah," has been completed and will be published early in 1952. Two reports of big game investigations, "Winter mortality of mule deer in Utah in relation to range condition" and "Food habits of mule deer in Utah," will also be published in 1952. The study of deer-sheep food habits will be completed and readied for publication.

In this year's annual report, significant findings from the big game-livestock range relationship, winter range, and spring-fall range projects are given. There is also a preliminary report on results obtained from studies of range enclosures in Nevada. Work on summer range projects was interrupted by Ellison's departure for Australia to participate in a Fulbright fellowship and Houston's absence on educational leave.

BIG GAME-LIVESTOCK RANGE

A knowledge of food habits of grazing animals is essential as a basis for managing range. Information on food habits is especially important on big game-livestock range, where use by both kinds of animals must be correlated, to insure sustained forage production and watershed protection. This involves not only a knowledge of forage preferences but of grazing patterns and seasonal use in relation to forage supply.

In previous annual reports the following important points on deer-livestock food habits have been brought out:

(a) Even though deer use areas inaccessible to livestock and sometimes concentrate on such areas, they commonly make heavy use of the same feedgrounds as sheep and cattle.

(b) Cattle mainly eat grass where it is available but on many Utah ranges, especially those overstocked, they use choice deer browse heavily. Deer use grass heavily in early spring, but only in small quantities at other times of the year. Some forbs and shrubs are very palatable to both deer and cattle.

(c) Sheep and deer diets are generally very similar. The chief difference is in the greater amount of grass eaten by sheep. There are some exceptions but in general the forbs and shrubs palatable to deer are also palatable to sheep.

(d) Forbs comprise a large percentage of deer forage in summer. Some of these show high preference ratings and should be considered as "key species" in the management of deer summer range.

Deer forage utilization in the late fall.--Forage utilization as measured by samples from 88 stomachs of mule deer, collected during the hunting seasons of 1948-51 on the Fishlake and Manti-LaSal National Forests, is shown in table 2.

Browse made up the greatest part of the identifiable stomach sample material in all range types. This confirms previous reports that browse is increasingly used in the fall as forbs become dry. However, forbs that remain semigreen and do not shatter badly, such as lupine (Lupinus spp.) and tall larkspur (Delphinium spp.) are eaten readily by deer in late fall.

Deer apparently like a little grass and conifer leaves mixed in their fall diet as indicated by the presence of these in small amounts in practically all stomach samples. Rarely was one collected that contained a large percentage of grass. Only in the ponderosa pine-oak-aspen type did grass consistently make up a substantial part of the material examined. A shortage of palatable browse and forbs may account for the heavy use of grass in this type.

Wherever available, Oregon grape (Mahonia repens) was preferred over other species. Fallen aspen leaves were also important forage although less used than Oregon grape where they occurred together. Curlleaf and true mountain-mahoganies (Cercocarpus ledifolius and C. montanus), bitterbrush (Purshia tridentata), and boxleaf myrtle (Pachistima myrsinites) rate high as fall deer forage as indicated by close utilization of these plants. On the average, they made up only small percentages of deer stomach samples due to their scarcity or scattered occurrence. However, where they were available in sufficient quantities they formed large percentages of the stomach contents. Other species such as snowberry (Symphoricarpos oreophilus) and sagebrush (Artemisia tridentata) are abundant in many areas but were used in very small amounts, with one exception in the pinyon-juniper type. Here deer were forced to eat large quantities of sagebrush (chiefly a winter forage) because very little better forage was available.

By comparison with results published in previous annual reports, this study shows that the late fall diet of deer differs considerably from summer and early fall diets. Much of the highly preferred late fall browse, including Oregon grape, curlleaf mountain-mahogany, and boxleaf myrtle, is little used in summer and the mass of fallen aspen leaves is not available until fall. Oak (Quercus gambeli) is a notable exception on the heavily stocked Oak Creek deer range, where it is a major deer forage in both summer and fall.

Table 2.--Stomach content of mule deer on various range types in central Utah, October 20 to November 3, 1948-51[1] (based on samples taken from 88 stomachs)

Class of forage and species	Range type						
	Spruce-fir[2]	Aspen-spruce-fir[2]	Aspen-mountain brush[2]	Ponderosa pine-oak-aspen[3]	Mountain brush[2]	Mountain brush[4]	Pinyon juniper[3]
	Percent of identifiable material						
Browse:							
Fallen aspen leaves	50.9(1)	28.4(1)	67.3(1)	27.4(2)	1.6(3)	--	--
Oregon grape	9.8(3)	43.3(1)	3.2(3)	29.4(2)	29.7(2)	7.8(3)	1.5(3)
Silver sagebrush	3.0(3)	3.0(3)	.2(3)	--	--	--	--
Sagebrush (other)	--	.4(3)	--	3.7(1)	.9(1)	1.1(1)	45.2(1)
Snowberry	.7(1)	1.2(1)	.8(1)	1.2(2)	.3(1)	.1(3)	--
Rabbitbrush	--	1.4(3)	--	--	4.4(2)	.1(2)	--
Manzanita	--	--	--	.7(3)	--	1.8(3)	9.3(3)
Gambel oak	--	4.4(3)	--	7.7(1)	11.4(1)	49.7(1)	5.7(3)
Curlleaf mountain-mahogany	--	.1(3)	--	--	22.2(2)	6.9(3)	--
True mountain-mahogany	--	.6(3)	--	--	5.8(3)	.3(3)	27.2(2)
Bitterbrush	--	.2(3)	--	1.5(3)	3.5(3)	4.8(2)	1.1(3)
Boxleaf myrtle	--	T(3)	--	.4(3)	15.7(2)	1.7(3)	.4(3)
Coniferous foliage	3.9(1)	5.6(1)	4.2(1)	6.4(1)	.2(1)	.2(1)	1.1(1)
Other	.1	.8	2.5	--	1.4	3.5	2.3
Total browse	68.4	89.4	78.2	78.4	97.1	78.0	93.8
Forbs:	28.1(2)	7.7(1)	20.6(2)	1.8(3)	1.7(3)	7.3(3)	.4(3)
Grasses:	3.5(1)	2.9(1)	1.2(1)	19.8(1)	1.2(1)	14.7(1)	5.8(3)
No. stomachs analyzed	11	22	5	15	7	18	10

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[1] Figures in parentheses indicate availability: (1) plentiful, (2) common but distribution or amount limited, and (3) scarce or of only spotty occurrence.

[2] Monroe Mountain and adjacent range.

[3] Elk Ridge.

[4] Oak Creek.

Much of the choice late fall deer forage, including fallen aspen leaves, Oregon grape, curlleaf mountain-mahogany, and boxleaf myrtle, is usually grazed but little by livestock on the areas studied. Deer therefore probably offer relatively little competition with livestock in late fall and make use of much forage which would otherwise be left unused.

Results of this study will be given in greater detail in Intermountain Forest and Range Experiment Station Research Note No. 2.

Competition between deer and sheep

One of the foremost problems inherent in any consideration of big game and livestock range relationships is competition. It is often said that deer and sheep competition is unimportant because the animals choose different foods and use different parts of the range. Study of deer and sheep food habits in several vegetal types on spring and summer range in central Utah reveals that the problem may not be dismissed so lightly.

Spring food habits.--The spring range on the study area was largely made up of two vegetal types, the sage-oak and pinyon-juniper. The following tabulation shows the composition of the deer and sheep diets and the spring range herbage.

	Percent of diet						Percent of
	Sage-Oak		Pinyon-juniper		Average		total herbage
Class of forage	Deer	Sheep	Deer	Sheep	Deer	Sheep	both types
Grasses and sedges	38	44	91	47	65	46	11
Forbs	17	19	7	5	12	12	5
Browse	45	37	2	48	23	42	84

It is apparent from this tabulation that the choice of each animal for forage classes was quite similar in the sage-oak type; the deer diet was almost exclusively grass in the pinyon-juniper type while sheep utilized browse and grass in about the same proportion. There is considerable overlap when diets are considered from the standpoint of the average for both types. However, the fact that deer and sheep show preferences for the same forage classes would lead to conflict only if their choice of species was similar. The six most prominent species in each diet are compared below:

	Percent of diet		Percent total
Species	Deer	Sheep	utilization
Artemisia tridentata	4	--	T
Cercocarpus montanus	13	26	33
Chrysothamnus lanceolatus	--	10	36
Agropyron cristatum	--	5	50
Agropyron spicatum	7	4	14
Poa fendleriana	43	25	59
Poa pratensis	4	3	85
Sitanion hystrix	4	--	4
Total	75	73	

T = trace

This comparison illustrates the great similarity in choice of species. The fact that none of these species, with the exception of _Poa pratensis_, was excessively utilized is indicative that selection of species was not unduly influenced by their scarcity. It is evident then, that there must be serious conflict between deer and sheep on those ranges where the supply of preferred forage is not adequate to meet the needs of both. Actually, the likelihood of competition is minimized because deer graze the types in early spring when most forage is in the active growing stage while sheep graze in late spring or early summer after much of the vegetation is mature.

Only about 13 percent of the 1,600 acres that constitute the spring range of the study area is grazed exclusively by deer; the rest is grazed by both.

Summer food habits.--The summer range of the study area embraces a much wider variety of vegetal types. It is the grazing area that receives the longest period of use by deer and sheep at the same time and therefore represents the zone of greatest potential conflict. Table 3 shows deer and sheep diets and total herbage by classes of vegetation.

Table 3.--_Composition of deer and sheep diets and total herbage by vegetal classes on summer range, Utah, 1947-50_

Types	Percent of diet					
	Grasses and sedges		Forbs		Browse	
	Deer	Sheep	Deer	Sheep	Deer	Sheep
Spruce-fir	5	14	74	50	21	36
Aspen	4	35	72	47	24	18
Currant-snowberry	8	33	33	48	59	19
Sage-chokecherry	15	26	56	23	29	51
Sage-snowberry	8	42	90	13	2	45
Sage-grass	0	57	100	41	0	2
Average	7	35	71	37	22	28
Total herbage	24		22		54	

The prominence of forbs in the deer diet is evident from the fact that they comprise the largest part of the diet in all types but one. In the sheep diet forbs are also prominent in most types and in the average diet for all types. The utilization of browse by deer and sheep varies considerably within and between types, but the averages for the summer are similar. The greatest contrast between the two diets is found in the use of grass. The volume of grass in the sheep diet is much larger than in the deer diet in every type and is five times as large for the average of all types.

In addition to the comparison of deer and sheep diets on the basis of forage classes it is of interest to compare them from the species standpoint, because, as indicated previously, the element of conflict begins at the species level and not at the forage class level.

This study showed that the same eight species made up two-thirds or more of both diets in the spruce-fir, currant-snowberry, and sage-chokecherry types. The similarity was less pronounced in the other three types although more than half of both diets in the aspen type was made up of the same eight species. In the sage-snowberry and sage-grass types a large part of the sheep diet consisted of browse and grass species which deer did not use. The analogy in choice of species is evident in a comparison of the ten species most prominent in the summer diet of each animal.

Species	Percent of diet		Percent total utilization
	Deer	Sheep	
Populus tremuloides	6	7	29
Prunus virginiana	3	5	42
Symphoricarpos oreophilus	5	7	15
Aster spp.	2	--	52
Castilleja linariaefolia	5	--	44
Lupinus alpestris	15	--	59
Mertensia leonardi	--	9	72
Penstemon watsoni	6	--	35
Taraxacum officinale	11	7	38
Trifolium sp.	16	6	51
Carex spp.	--	4	44
Festuca rubra	--	4	21
Poa fendleriana	--	10	51
Stipa lettermani	2	5	30
Total	71	64	

It is obvious from this comparison that out of the ten species which were outstanding in each diet, six were prominent in both diets. Here, as in the case of spring range, one may logically conclude from the utilization figures that forage preferences reflect a free choice, unhindered by scarcity.

There is then the probability of direct and severe competition, particularly for forbs and browse, on areas where the volume of preferred foods is insufficient for both. It is significant that the nature and extent of conflict may vary considerably with type. For example, the likelihood of competition in the sage-snowberry type where preferences are quite different is much less than it is in the spruce-fir type where they are similar.

The conclusion that similarity of diet results in conflict between deer and sheep is based on the premise that both animals graze the same area. This premise is largely true although it is well known that deer will frequent areas not used by sheep because of insufficient or undesirable forage or unfavorable terrain. Unfortunately, the difference in areal use cannot be generalized because it varies with each locality. A survey of the 10,000-acre study allotment showed that deer use all of the area with the exception of inaccessible rocky cliffs and ledges, whereas sheep grazing is confined to approximately 80 percent of the area. Thus there are 2,000 acres which provide forage for the exclusive use of deer and the extent of competition is thereby reduced. It should be pointed out, however, that within the study area the greatest deer utilization occurs where sheep also graze.

In managing big game-livestock range it is important to recognize existing competition and adjust numbers of grazing animals so that total use does not exceed safe use. For example, if 60 percent is considered safe use for the important sheep forage species and deer utilize 15 percent of this forage, the carrying capacity for sheep should be based on 45 percent use. Fifteen percent use by deer appears very light and may therefore be considered to be insignificant. Actually it means that 25 percent fewer sheep can be grazed or else the important forage species will be overgrazed. In a similar manner, any use by livestock of key deer forage species on important deer winter range of limited extent will reduce the size of deer herd that can be maintained.

WINTER RANGE

Supplemental feeding of range sheep.--In the winter of 1950-51 a supplemental feeding test was conducted in connection with grazing intensity studies in pastures at the Desert Experimental Range. Four lots of sheep were selected at random. One of these was maintained throughout the winter in moderately grazed pastures without supplemental feed. The second and third lots were placed in moderately grazed pastures and fed 1/2 to 1 pound of supplemental rations every other day. The fourth lot wintered in heavily grazed pastures and received the same amount of supplements as lots two and three. All sheep were watered every day except when snow was readily available.

The sheep were weighed at the beginning of the study in November and again in April to measure the effects of the three treatments. The ewes that wintered in moderately grazed pastures without supplemental feed gained an average of 6 pounds per head, those in moderately grazed pastures with supplemental feed, 13 pounds, and those in heavily grazed pastures with supplemental feed, 4½ pounds.

The cost of supplemental feed was $2.00 per head during the winter grazing period. It therefore cost that much to get 1½ fewer pounds per head, if weights obtained in moderately grazed pastures without supplemental feeding are compared with those obtained in heavily grazed pastures where supplements were fed. Furthermore, weight gains in moderately grazed pastures were 8½ pounds per head greater than those in heavily grazed pastures even though the same amount of money was spent for supplements.

Forage production on the winter range in 1950-51 was extremely short and herbage was dry because of drought during the growing season. The forage was apparently lower in nutritional quality than usual, because sheep on moderately grazed range failed to gain as much as they did in previous years. The low nutritional quality of the forage is also indicated by the 7-pound differential in weight gain between ewes that received supplemental feed and those that did not on moderately grazed pastures.

At best, forage on the winter range provides only a subsistence diet for sheep and supplemental rations of grain or cotton seed pellets are necessary to insure adequate nutrition and weight gains. As this study shows, however, it is doubtful if it is economically justifiable to provide supplemental feeds year after year on heavily grazed range.

Forecast of forage on winter range, 1951-52.--From data collected at the Desert Experimental Range between 1938 and 1947 it was found that herbage production as measured in October was closely related to precipitation received during the preceding 12 months. This close relationship provides a basis for estimating or predicting the annual forage crop from precipitation received on winter ranges. The estimate can be made with great accuracy if precipitation between October and December is given twice the weight and that received between January and March one and a half times the weight of summer and early fall precipitation. The equation for estimating herbage yield from precipitation is $Y = 31.44X - 76.18 \pm 21.33$ where Y is the estimated herbage yield and X is the precipitation for the preceding 12 months weighted by multiplying precipitation for October-December by 2, January-March by $1\frac{1}{2}$, and April-September by 1.

Certain allowances need to be made in these estimates because of the carry-over effects of precipitation during previous years or the influence exerted on yields which results from the character or intensity of the precipitation. Extreme drought in a previous year tends to lower the yield, but above-average precipitation tends in most cases to increase production the following year.

Forecast of herbage yield made in October for winter range based on precipitation showed that herbage production was about 70 percent of average at the Desert Experimental Range. In northern Nevada the yield was indicated to be about average. Estimates for east-central Nevada and western Utah indicated that production would be from 10 to 40 percent below average and for southern Utah, from 30 to 60 percent below average. These estimates were published in the October Woolgrower.

Research n n Desires?

SPRING-FALL RANGE

Chemical composition of forage.--Studies of chemical composition of bluebunch wheatgrass (Agropyron spicatum), arrowleaf balsamroot (Balsamorhiza sagittata), and some associated species on the upper Snake River Plains were made in cooperation with the University of Idaho. Although chemical analysis of forage does not directly measure nutritive value, the close relation between digestibility and chemical composition indicates that composition is a good index of nutritive value.

Stage of maturity was the most important factor influencing composition of wheatgrass and balsamroot. As the plants matured, the percentage of crude protein and phosphorus decreased rapidly, whereas that of nitrogen-free extract and crude fiber increased. The proportion of crude fat in wheatgrass remained constant or made slight increases, but in balsamroot it decreased markedly with maturity. Percentage calcium also remained fairly constant in wheatgrass, but increased considerably in balsamroot. Calcium-phosphorus ratio in wheatgrass increased mostly because of decrease in phosphorus, whereas the greater increase of this ratio in balsamroot was caused by both increase in calcium and decrease in phosphorus. The low content of crude protein and phosphorus and the wide calcium-phosphorus ratio were the most striking features of the herbage in fall.

Chemical composition and seasonal trends were similar in each of the 4 years that collection were made, although there was considerable variation in flower stalk production and herbage yield. Apparently both reproductive activity and yield were more sensitive to minor variations in weather than was chemical composition.

There was great difference in chemical composition of leaves, flower stalks, and heads of balsamroot. Heads were high in protein, fat, and phosphorus, but these components were sharply reduced after seed dissemination. In contrast to the heads, flower stalks contained the largest proportion of crude fiber, but were the poorest source of all other constituents. Leaves, which furnish most of the forage, had the lowest crude fiber content, but the highest concentration of nitrogen-free extract and calcium, and were also fairly high in protein, fat, and phosphorus.

As with wheatgrass and balsamroot, the percentage of crude protein was initially high in associated species and decreased as the growing season advanced. The proportion of calcium in bluegrass (Poa secunda) remained fairly constant throughout the spring growing season but increased in hawksbeard (Crepis acuminata) and lupine (Lupinus caudatus). Percentage phosphorus decreased in bluegrass and lupine as the season advanced but increased in hawksbeard. With the exception of this phosphorus increase in hawksbeard, trends in chemical composition of bluegrass and the forbs were similar to those of wheatgrass and balsamroot, respectively. Trends in calcium and phosphorus content of threetip sagebrush (Artemisia tripartita), downy rabbitbrush (Chrysothamnus *puberulus*), and bitterbrush (*Purshia tridentata*) were more variable, but in general calcium content remained constant, and phosphorus content either decreased or remained constant as the season advanced.

Apparently chemical composition is not closely associated with reproductive activity. Although there was wide variation in flower production during the period of study, this variation was not reflected in chemical composition. Trends in composition of the various species were similar despite wide variations in dates of comparable developmental stages. It seems, then, that changes in composition follow a fairly constant pattern through the growing season independent of reproductive processes.

Although data are available for few species, certain differences in chemical composition of grasses, forbs, and shrubs are indicated. Percentage protein in grasses and forbs is high at the start of the growing season, but decreases rapidly as the herbage matures and is low by fall. The protein content of shrubs, however, is much lower at the beginning of the season, but it decreases slowly and is considerably higher than that of the grasses and forbs in the fall. Percentage calcium appears high in forbs, intermediate in shrubs, and low in grasses; in grasses and shrubs it is fairly constant throughout the season, but in forbs it increases as the season advances. In general, the proportion of phosphorus is higher in forbs and grasses than in shrubs, but it decreases rapidly in forbs and grasses and is low by fall whereas it maintains a more constant level in shrubs.

During the spring grazing season, the high content of protein, phosphorus, and fat for wheatgrass and balsamroot and the low proportion of crude fiber indicate that ranges supporting these and other grasses and forbs supply a good diet for livestock. Furthermore, the narrow calcium-phosphorus ratio is well suited to livestock requirements. In the fall, however, the same forage is but a poor roughage, low in protein, phosphorus, and fat, considerably higher in crude fiber, and having a wide calcium-phosphorus ratio. Although both protein and phosphorus content of mature grasses and forbs during the fall season are much too low to supply minimum requirements of grazing animals, the presence of shrubs on these ranges at least helps to correct the deficiencies. Shrubs may not be eaten in sufficient quantities to provide an optimum diet, but even the relatively unpalatable sagebrush is utilized to some extent, especially in late fall. Although serious nutritional deficiencies are not apparent on these sagebrush-grass fall ranges, supplemental fall feeding may be a desirable practice, particularly on ranges which support only a few shrubs.

Effects of spring and fall grazing on vegetation.--Sagebrush-grass range plays an important part in the western livestock industry. Because of its intermediate topographical position between low wintering areas and high summer range, it is used in both spring and fall. Proper management, therefore, depends upon a knowledge of relative effects of grazing during these two seasons.

In 1920 two adjacent 80-acre pastures were established on sagebrush-grass range at the U. S. Sheep Experiment Station. Between 1923 and 1949, pasture 1 was grazed only in the fall at the average rate of 43 sheep days per acre whereas pasture 2 was grazed both in spring and fall at the average rate of 29 sheep days per acre (19 in the spring and 10 in fall). Use as breeding pens and holding pastures, rather than actual grazing capacity, largely determined these rates of stocking.

Vegetation of the two pastures was similar at the beginning of the study; grasses and shrubs each composed roughly 40 percent and the forbs, 20 percent of the total. As judged by recent standards for sagebrush-grass range, both pastures were originally in good condition.

After 25 years (1949), the two pastures differed greatly; pasture 1 was still in good condition but pasture 2 was in poor condition. In pasture 2 shrubs had increased to more than three-quarters of the total vegetation, whereas shrub production in pasture 1 was still less than half of the total.

Bitterbrush was apparently reduced most by fall grazing. Although quantity of bitterbrush in the two pastures was originally equal, its 1949 production in pasture 1 was less than half that of pasture 2. Forb production in pasture 2 decreased to 5 percent of the total whereas it increased to 29 percent of the total in pasture 1. Arrowleaf balsamroot, often the most important forb on sagebrush-grass range, was reduced in pasture 2 to less than 1 percent of the amount in pasture 1. Grass production also differed greatly in 1949, making up 24 percent of the total in pasture 1 but only 16 percent in pasture 2. All of the desirable grasses were more abundant in pasture 1, whereas the relatively undesirable squirreltail (Sitanion hystrix) and cheatgrass (Bromus tectorum) were more abundant in pasture 2.

The large increase in shrubs in pasture 2 and the corresponding decrease in grasses and forbs occurred during the initial 7-year period when average spring stocking rate was very heavy (34 sheep days per acre). Since that time there has been but little improvement even though spring stocking has been light (less than 14 sheep days per acre). It appears, then, that spring is the critical grazing season and that ranges damaged by heavy spring use will recover slowly, even under light grazing. Fall grazing apparently has little effect on grasses and forbs, but may cause a reduction in shrubs; therefore, some care must be taken to prevent undue damage to such desirable shrubs as bitterbrush.

Ecological effects of planned burning.--The manuscript, "Ecological Effects of Planned Burning of Sagebrush-Grass Range on the Upper Snake River Plains," has been completely revised and will be resubmitted to Washington. It provides information on effects of burning on both vegetation and soil over a 15-year period and lists the following conclusions with respect to planned burning of sagebrush-grass range:

1. Burning is beneficial to shrubs with a strong sprouting habit and to rhizomatous grasses and forbs, whereas nonsprouting shrubs, suffrutescent forbs, and fine bunchgrasses are severely injured. Other species are only slightly affected.

2. Because of this variable response, composition of the stand should be carefully considered when planning a sagebrush burning operation. A high proportion of undesirable sprouting shrubs or of desirable fine bunchgrasses and suffrutescent forbs may preclude successful burning.

3. Although total yield of grasses and forbs is greatly increased within 2 or 3 years after burning, much of this early increase may be relatively short-lived. Increased availability of forage and ease in handling livestock are often the main benefits.

4. Total herbage production is considerably higher on unburned areas, clearly as a result of the much greater amount of sagebrush. Apparently sagebrush is able to use some moisture which is not available to grasses and forbs; therefore, removal of sagebrush allows only partial replacement by herbaceous vegetation.

5. Organic matter and nitrogen are slightly reduced in the top half-inch of soil by burns of heavy intensity, but these reductions are only temporary.

6. The best results are apparently produced by burns of light intensity, but these must be sacrificed in order to secure a satisfactory coverage.

7. Normally sagebrush reestablishment following planned burning is a gradual process, but occasionally sagebrush seedlings become established the following year on burned areas regardless of amount of grass before burning or management after burning.

8. The goal of sagebrush burning should be consistent with the climax cover. Repeated burning to keep out sagebrush might result in the loss of many desirable species and produce objectionable stands of rabbitbrush and horsebrush (Tetradymia canescens var. inermis) with a herbaceous cover dominated by thickspike wheatgrass (Agropyron dasystachyum) and plains reedgrass (Calamagrostis montanensis). The objective of range improvement on the upper Snake River Plains through planned burning should not be complete eradication of sagebrush but the attainment of an open stand with a scattering of other shrubs and a continuous understory of perennial grasses and forbs.

ENCLOSURE STUDIES IN NEVADA

Between 1937 and 1939 a series of range enclosures was established throughout Nevada. This work was undertaken cooperatively by the Intermountain Forest and Range Experiment Station, the Bureau of Land Management, the Indian Service, the Forest Service, and the University of Nevada. The purpose was to study the trend of native range under grazing and under protection. In all, 28 enclosures were built, of which 16 are in the big sagebrush type and 12 in the salt-desert shrub type. Each one covers an area of 4 acres. A small part of several of the enclosures was also fenced with fine mesh wire to exclude small foraging mammals. Enclosures and surrounding range in both types were examined in 1942, 1946, and 1951.

Comparisons inside and outside enclosures in the big sagebrush type show that natural revegetation is a slow process but they also indicate that differential changes are taking place. For one thing, the vigor of plants inside the enclosures is uniformly better than that on adjacent grazed areas. Another noticeable feature is the general lack or reduction of annuals in enclosures as compared with the grazed area. The increase in the amount of litter remaining on the ground is another feature which is readily apparent in the enclosures. The most striking difference noted is the more abundant vegetation in the rabbit-proof parts of enclosures.

Inspection of the 12 enclosures in the salt-desert shrub type has also revealed some interesting trends and conditions. Most apparent is the harshness of the site and, consequently, the difficulty in maintaining or improving the desirable forage species under grazing use. Preliminary data show an increase in herbage production of shrubs both inside and outside the enclosures. There is, however, generally a greater increase of such desirable species as winterfat inside the protected areas. Outside there has been a greater increase in such species as rubber rabbitbrush. Although there has been a general increase of some grasses, the increase inside the enclosures is much greater than on the grazed areas. This is true of such species as Indian ricegrass and bottlebrush squirreltail. One species, Sandberg bluegrass, seems to be decreasing in some localities with the decrease being greater on the grazed area than within the enclosure. Annual weeds, such as Russianthistle and cheatgrass, are generally decreasing in the enclosures and increasing on the grazed areas. In some instances there has been an increase of Russianthistle but the increase is much greater on the grazed portion of the range than in the enclosure. Here, as on the sagebrush type, the litter accumulation was noticeably greater in the enclosures and plant vigor was generally better in the enclosures.

What kind of use?

PROGRAM FOR 1952

Summer range.--Complete preparation of manuscripts "Subalpine vegetation of Wasatch Plateau, Utah" and "Influence of pocket gophers on vegetation of subalpine grassland in central Utah."

Big game-livestock range relationships.--(1) Complete report on deer-sheep food habit study. (2) Summarize and report on deer-cattle food habit study. (3) Continue studies on condition and trend on big game range with special emphasis on the mountain brush type, both for livestock and game. (4) Continue studies on proper use of game forage species.

analyze for Halogeton inside & outside.

Winter range.--(1) Complete preparation of manuscripts "Management of winter sheep ranges in the Intermountain region" and "Deer utilization of oakbrush range." (2) Prepare report on vegetation inside and outside Nevada enclosures. (3) Continue grazing treatments of pastures at the Desert Experimental Range.

Why not desert.

Spring-fall range.--(1) Complete preparation of manuscripts, "Ecological trends after planned burning of sagebrush-grass range on the upper Snake River Plains," "Variations in chemical composition of bluebunch wheatgrass, arrowleaf balsamroot, and associated range plants," and "Larkspur eradication trials." (2) Complete analysis of vegetation and sheep weight data from pasture grazing studies at Dubois and prepare a report. (3) Analyze quadrat, inventory plot, plant development-seasonal yield, soil moisture, and weather records and prepare a report. (4) Continue routine grazing treatments of pastures and collection of data from climatic quadrats and inventory plots.

Utilization standards.--(1) Complete report on indicators for judging condition and trend in aspen type. (2) Continue studies of aspen range condition. (3) Continue experiment to test productivity of range in openings as compared with that under aspen canopy as a basis for more accurate judgment of condition and trend.

RESEARCH IN RANGE RESEEDING

Research on artificial seeding during 1951 has been devoted mainly to analysis and completion of established studies. Special emphasis has been given to species adaptability investigations from the sagebrush through the subalpine vegetal zones. Approximately 1,000 species and strains have been under trial and observation; many for a long enough time and under wide enough differences in site to give conclusive evidence as to their place and value in seeding programs. Because of the urgent need for an improved plant cover in the drier areas of the Intermountain region, species adaptability trials have been extended into the Colorado River Basin and the Great Basin in Utah and Nevada. Preliminary results of some of these trials are reported below.

Analysis of the effects of various grazing treatments on crested wheatgrass pastures at Benmore and Ephraim, Utah, has also been a major activity. Variations in response of cattle at Benmore and sheep at Ephraim and in the response of vegetation are beginning to show that different types of management have differing effects on the survival of crested wheatgrass in such reseeded pastures.

Other phases of study which are reported include methods of removing competition (principally by means of chemicals), plant breeding, and problems in halogeton control.

SPECIES ADAPTABILITY

Species adaptability trials have been under way in Utah for 14 years, primarily in the sagebrush (spring-fall range) and mountain brush (early summer range) types. In recent years trials have also been extended into aspen, subalpine, valley saltgrass, and salt-desert shrub types. Current reports of the results of some of these tests are given in the subsections that follow.

Adaptability tests in the Colorado River drainage

Because of the urgent need for artificial seeding in dry areas of the Colorado River drainage, 82 species and strains were planted on four representative sites in the fall of 1950. Two of the trial areas are on the extensive Mancos clay soil type and two on sandy soil types in southeastern Utah, where large-scale seeding is badly needed. Although the period of spring seedling establishment and the summer growing season were among the driest on record, fair seedling stands were obtained of some species. Table 4 shows the relative success ratings of species producing seedling stands.

Some later mortality is expected, but there are further prospects of seedling stands in 1952; inspection showed that considerable seed failed to germinate in 1951. Results from these trials should provide a more reliable guide as to species which merit wider testing. The superior showing of squirreltail (lot 27) indicates that it may be useful on desert ranges. Russian wildrye should be further investigated because it has good drought-enduring qualities and is also tolerant of high salt concentrations.

Table 4.--Relative ratings of 1951 seedling stands on four desert sites within the Colorado River drainage in southeastern Utah[1/]

Species and lot number	Castle Dale (Mancos clay)	Buckhorn Flats (sandy soil)	Thompson (sandy soil)	Cisco (Mancos clay)
Squirreltail (27)	6	5	9	4
Intermediate wheatgrass	6	6	6	3
Crested wheatgrass (Fairway 80)	6	4	8	1
Desert wheatgrass (2B)	6	6	--	1
Amur wheatgrass (1A)	6	5	5	2
Crested wheatgrass (Standard 78)	6	4	6	1
Crested wheatgrass (Turkestan spreading 28A)	6	4	6	1
Belvedere summercypress (1A)	0	7	8	1
Pubescent wheatgrass (62)	4	4	3	2
Bearded bluebunch wheatgrass (34)	5	2	4	1
Squirreltail (32)	2	2	7	1
Beardless bluebunch wheatgrass (55)	4	2	4	1
Russian wildrye (42)	4	1	4	2
Squirreltail (30)	2	2	6	0
Squirreltail (29)	1	1	7	0
Winterfat (12)	0	0	7	0
Fourwing saltbush (21)	0	1	4	0

[1/] Meaning of ratings: 0 failure; 1-2 very poor; 3-4 poor; 5-6 medium, 7-8 good; 9-10 very good.

The complete lack of stands from seeding of several drought-enduring natives, such as dropseed, grama, and galleta, is disappointing. These are warm season grasses and practically all success on Utah deserts has been with cool season plants. Evidently conditions suitable for establishment do not often occur for warm season plants. Failure of some species is associated with tardy germination, attributable to a hard seed coat. Sulfuric acid scarification has been found a means of improving germination of some species. Extended field trials are being planned to test the feasibility of different types of scarification treatments.

Species for spring-fall range

Considerable effort in the past has been directed to determining species suited to spring-fall ranges where average annual precipitation may vary between 8 and 16 inches. Table 5 shows 1951 yields and plot ratings of 13 best species 8 years after establishment on three representative spring-fall sites. Precipitation ranges from 8 inches on site 1 to 14 inches on site 3. Except for precipitation, sites are comparable. As shown in table 5, crested wheatgrass gives best yields and stands on the site having 8 inches average annual precipitation. The next best is Russian wildrye, which although not yielding as much herbage, is indicated by these tests as being of potential use for seeding such sites. Although other species maintain themselves, yields are too low to justify using them in large-scale seeding programs.

Table 5.--Air-dry yields (pounds per acre) and stand ratings1/ of 13 species on three sites in the spring-fall zone 8 years after establishment (1951 data)

Species	Site 1		Site 2		Site 3	
	Yield	Rating	Yield	Rating	Yield	Rating
Crested wheatgrass (Fairway)	1,150	10	1,425	10	2,117	10
Crested wheatgrass (Standard)	800	9	1,425	9	1,823	10
Tall wheatgrass	120	1	225	3	3,200	10
Thickspike wheatgrass	20	1	580	3	573	5
Beardless bluebunch wheatgrass	365	3	1,500	8	2,400	10
Bearded bluebunch wheatgrass	190	2	1,450	8	2,317	8
Intermediate wheatgrass	475	4	300	8	3,000	10
Pubescent wheatgrass	390	4	425	7	2,500	9
Bluestem wheatgrass	110	1	400	9	1,116	8
Smooth brome	0	0	385	4	400	4
Giant wildrye	30	1	950	5	3,800	9
Russian wildrye	624	6	1,750	10	1,367	9
Bulbous barley	110	2	575	4	1,033	8
Annual precipitation (inches)	8		10		14	

1/ Meaning of ratings: 0 failure; 1-2 very poor; 3-4 poor; 5-6 medium; 7-8 good; 9-10 very good.

On the site with annual precipitation of 10 inches, bluebunch wheatgrass and Russian wildrye not only maintained their stands but are producing slightly more herbage than crested wheatgrass. The Whitmar strain of bluebunch wheatgrass developed by the Soil Conservation Service at Pullman, Washington, is particularly aggressive in establishment and ability to maintain stands. Both bluebunch wheatgrass and Russian wildrye retain their succulence and are palatable in late spring and early summer and would therefore be useful in extending the grazing season on sites having at least 10 inches of precipitation.

Bluestem wheatgrass, a sod grass, has maintained a good stand with 10 inches of precipitation, but yield is not comparable to that of the bunchgrasses mentioned. However, because of its rhizomes, it has the ability to spread into openings and thus make a more complete ground cover, and for this reason may often be desirable in mixture with bunchgrasses.

Giant wildrye, tall wheatgrass, intermediate wheatgrass, and pubescent wheatgrass produce the highest yields on the site having 14 inches of annual precipitation. These species, particularly the last three, are sometimes suggested for reseeding on drier ranges, but results so far indicate that they would not produce enough herbage to warrant their use on a large scale at a much lower level of precipitation.

There is a need for an adapted legume to grow in mixtures with the grasses. Chickpea milkvetch (*Astragalus cicer*), sicklepod milkvetch (*A. falcatus*), and alfalfa are the most promising. However, trouble is encountered in obtaining stands, particularly on ranges with less than 10 inches of precipitation. Strain trials were begun in 1951 in cooperation with the Bureau of Plant Industry to test adaptability of several pasture types of alfalfas which show evidence of drought tolerance.

Species for valley saltgrass range

Trial plantings were started in 1944 to determine possibilities for increasing forage yields and seed production on range lowlands too salty for most crops. Seventeen grasses were planted on 2 acres of land where soluble salts in the top 6 inches averaged 2,300 parts per million. The pH ranged from 7.3 to 8.8, and the depth to water table was between 18 and 36 inches. Table 6 shows that tall wheatgrass and tall fescue were outstanding in production of both herbage and seed. On this site meadow fescue, awned wheatgrass, mountain rye, mountain brome, reed canarygrass, big bluegrass, and one strain of slender wheatgrass proved total failures after the first 2 years and are not included in the table.

In 1948 seven of these grasses were planted on land having moderate to heavy salt concentrations, soluble salts in some places exceeding 8,000 parts per million. Table 7 shows that in the high salt concentration area tall wheatgrass and Russian wildrye gave highest herbage yields in 1951. These two species are growing well in the area where salt concentration originally exceeded 8,000 parts per million. Where salt concentration exceeds 3,000 parts per million, the five other species listed do poorly.

Table 6.--Average herbage production (green weight) and seed yields of grasses sown in May 1944 on salty land

Species	Herbage production (1946 and 1948)	Seed yields (1945-47)
	Lbs./acre	Lbs./acre
Tall wheatgrass	17,990	833
Intermediate wheatgrass	10,348	272
Tall fescue	10,855	966
Tall oatgrass	7,960	467
Russian wildrye	7,215	285
Smooth brome	6,940	676
Crested wheatgrass (Fairway)	6,262	536
Crested wheatgrass (Turkestan standard)	5,605	540
Pubescent wheatgrass	5,460	147
Slender wheatgrass	3,435	340
Production of undepleted native saltgrasses	6,000	--
Production of depleted native saltgrasses	1,500	--

Table 7.--Herbage production (green weight) of seven grasses on land with high and moderate salt concentration

Species	Production	
	High salt concentration	Moderate salt concentration
	Lbs./acre	Lbs./acre
Tall wheatgrass	12,100	16,700
Russian wildrye	5,100	7,900
Tall fescue	1,290	12,000
Intermediate wheatgrass	1,400	7,800
Smooth brome	0	6,700
Crested wheatgrass	1,500	5,560
Reed canarygrass	160	2,400

Species for mountain ranges

Table 8 presents the 1951 yields and stand ratings of several species suitable for large-scale plantings on mountain ranges. Forty-seven of 59 other grasses and forbs show adaptability for seeding in the mountain brush zone and 34 and 24 of this total are adapted to the aspen and subalpine zones, respectively. Twenty-eight showing the most promise for pilot plantings are listed in table 9. It should be noted that these have not yet been tested in large-scale plantings. The greater number listed in both tables as adapted in mountain brush is attributable to the longer growing season, more favorable spring temperature and moisture, and greater choice of sites suitable for different species.

Table 8.--Herbage yields (green weight) and stand ratings[1] of grasses and forbs suitable for large-scale plantings on four mountain sites in central Utah, 1951

Species	Planting site: Mountain brush (7,100 ft. elevation)	Aspen openings (8,850 ft. elevation)	Aspen canopy (8,000 ft. elevation)	Subalpine (10,500 ft. elevation)
		Lbs./acre		
Grasses:				
Crested wheatgrass (Fairway)	3,300(10)	--	--	--
Crested wheatgrass (Standard)	3,300(10)	--	--	--
Intermediate wheatgrass	6,000(10)	20,000(10)	--	--
Bluestem wheatgrass	4,200(10)	7,500(8)	--	--
Slender wheatgrass	--	2,400(10)	900(8)	--
Tall oatgrass (commercial)	4,500(8)	6,500(10)	1,960(8)	5,000(9)
Tall oatgrass (Tualatin)	4,500(8)	6,400(10)	--	5,300(9)
Mountain brome	1,500(8)	3,400(9)	1,000(7)	4,000(9)
Smooth brome	3,600(10)	20,000(10)	650(5)	8,200(9)
Orchardgrass	3,900(7)	9,100(9)	935(6)	2,700(6)
Reed canarygrass	--	32,500(9)	--	5,500(7)
Timothy	--	3,350(9)	840(5)	4,000(7)
Kentucky bluegrass	--	--	1,235(7)	3,100(10)
Forbs:				
Alfalfa	15,000(8)	--	--	--
White sweetclover	1,000(3)	--	--	--
Yellow sweetclover	1,000(3)	--	--	--

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[1] Stand ratings are given in parentheses. Meaning of ratings: 3-4 poor; 5-6 medium; 7-8 good; 9-10 very good.

Table 9.--Herbage yields (green weight) and stand ratings[1] of grasses and forbs suitable for pilot plantings on four mountain sites in central Utah, 1951

Species	Planting site			
	Mountain brush	Aspen openings	Aspen canopy	Subalpine
	Lbs./acre			
Grasses:				
Amur wheatgrass	8,050(10)	5,500(8)	--	--
Thickspike wheatgrass	2,220(10)	2,650(10)	--	--
Tall wheatgrass	7,000(8)	--	--	--
Beardless bluebunch wheatgrass	4,000(10)	--	--	--
Pungent wheatgrass	2,100(10)	2,400(8)	--	--
Streambank wheatgrass	3,300(10)	--	--	--
Bearded bluebunch wheatgrass	6,200(8)	--	--	--
Awned wheatgrass	2,200(8)	2,800(10)	1,300(9)	--
Pubescent wheatgrass	3,100(10)	11,000(10)	--	--
Creeping foxtail	--	--	--	3,500(7)
Meadow foxtail	--	--	--	4,500(8)
Meadow brome	4,000(9)	5,750(9)	--	3,800(8)
Tomentose brome	--	3,800(8)	--	6,000(9)
Chinese wildrye	8,000(9)	6,250(10)	--	5,400(8)
Giant wildrye	30,000(9)	4,500(9)	--	--
Mammoth wildrye	18,000(8)	7,500(10)	--	--
Blue wildrye	6,000(10)	6,500(9)	1,050(8)	--
Russian wildrye	5,000(9)	4,750(8)	--	--
Creeping wildrye	6,750(10)	6,000(9)	--	--
Bulbous barley	7,000(10)	5,700(10)	--	--
Mountain rye	5,000(10)	--	--	--
Forbs:				
Chickpea milkvetch	24,500(10)	17,800(9)	--	9,800(8)
Sickle milkvetch	33,500(9)	10,500(5)	--	--
Cowparsnip	--	16,500(5)	700(5)	8,500(9)
Flatpea	24,000(8)	--	--	--
Mountain lupine	--	--	--	7,000(8)
Sweet anise	--	--	590(5)	3,500(6)
Showy goldeneye	1,300(7)	16,500(10)	1,200(5)	2,500(6)

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[1] Stand ratings are given in parentheses. Meaning of ratings: 5-6 medium; 7-8 good; 9-10 very good.

Trials of browse species in Utah

The need for browse is particularly keen in Utah on large areas of winter deer and elk ranges at the lower edges of the mountain brush zone. Because of difficulties in acquiring seed and getting initial stands, direct seeding of browse has not been employed. Comparative plantings of 40 species in 1946 on a mountain brush site show there are good prospects for future browse plantings.

Particularly outstanding because of their rapid development are fourwing saltbush, blue elderberry, black locust, golden currant, and smooth sumac. Smooth sumac and bittercherry show unusual ability to spread from underground rootstocks, so that even a single seedling is capable of developing well within a few years. Although not as high in herbage production as several other species, antelope bitterbrush demonstrates excellent ability to establish itself.

Browse reseeding on big game ranges in Idaho

In 1949, with the cooperation of the Idaho State Fish and Game Department and the Boise National Forest, the Intermountain Station intensified its program of investigations to determine suitable species and methods of planting for use in artificially restoring browse cover on winter game ranges in the granitic foothills north and east of Boise, Idaho. On south-facing slopes in the Payette River area stands of bitterbrush (*Purshia tridentata*) and other shrub species that were abundant and productive 20 years ago now furnish almost no forage to game during the winter. A locust infestation concurrent with overuse by a large deer population has so depleted the browse cover that except through artificial revegetation, a long period, perhaps more than a century, would be required for its rehabilitation.

In earlier reseeding trials bitterbrush gave promise of being useful for reseeding on the southwestern Idaho game winter ranges. The majority of the studies now under way in the Boise area are concerned, therefore, with that species. Other shrubs are being tested for adaptability under different levels of competition, but seed treatments and planting methods are in need of further refinement to insure a high degree of seedling emergence. Among the species that thus far appear to be useful for artificial revegetation on dry south-facing granitic slopes are big sagebrush, (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), *Eriogonum umbellatum*, curlleaf mountain-mahogany (*Cercocarpus ledifolius*), serviceberry (*Amelanchier alnifolia*), bittercherry (*Prunus emarginata*), and chokecherry (*P. virginiana melanocarpa*). The first three named are remarkable in that some of their seedlings can become established under the severe competition of cheatgrass (*Bromus tectorum*) and other annual weeds.

Bitterbrush reseeding studies.--Bitterbrush seed is easy to collect in large quantities, and the seed, with or without the husks, is easily handled and stored. Various lots of seed stored in cloth or paper bags in an unheated garage for from one to seven years show no loss of viability.

Seed dormancy of bitterbrush can be overcome by several weeks' exposure to a cool, moist environment, which is provided naturally when seeds are planted before winter. Planting may be done at almost any time in late summer and fall with assurance that germination will not occur until the favorable spring season. It is doubtful, however, whether bitterbrush seeds can remain in the soil through two winters and germinate the second spring after planting.

Survival of seedlings seems to be related to the date of emergence, and the date of emergence can be controlled to some extent by the seeding depth. In a comparison of planting depths of 1/4, 1/2, and 3/4 inch, the earliest emergence came from seeds planted at 1/4 inch. Almost all of the seedlings coming from that depth emerged during a warm period late in winter and froze while still in the cotyledon stage. Most seedlings from 1/2 inch emerged in March. These fared better, but the time of greatest mortality among them was before March 27. Most of the seedlings emerging from 3/4 inch did not appear until after March 27, and although the total number of seedlings was much less than from 1/2 inch, the very good survival rate among them resulted in comparable final numbers of first-year seedlings. These preliminary results suggest that seeding depths should therefore be between 1/2 and 3/4 inch.

Competing weeds and grasses have an inhibitory effect upon the growth and survival of bitterbrush and other browse seedlings. Where bitterbrush was seeded in undisturbed cheatgrass all of the seedlings died before the end of August of the first growing season. Where the cheatgrass stand had been eradicated, it was succeeded by an abundant crop of broadleaved annuals. In this type, the mortality of bitterbrush after early May was 52 percent. Additional mortality through the first winter and the following summer brought the figure to 66 percent. Where the bitterbrush seedlings were kept free of competing weeds the mortality rate was only 32 percent the first growing season and 35 percent for the first two years.

Besides increasing the likelihood of survival, the removal of competing annuals permitted more rapid growth of the bitterbrush seedlings that lived. This is shown in the tabulation below. Considering the better rates of survival and growth together, it can be seen that the second year's twig and leaf production from a given number of plants in the initial seedling stand was increased by almost 90 times as a result of competition removal.

Site Condition	Twig and leaf production Grams fresh weight per plant 1950	1951	Average plant height inches Nov. 1950	Nov. 1951
Weedy	0.2	1.3	0.9	4.2
No weeds	4.8	60.3	5.8	15.4

When bitterbrush is planted in the cheatgrass type, competition must be removed from within a least a 1-foot radius of the point of seed placement and kept out during the first growing season if the growth and survival rates are to be kept at reasonable levels. It has been found that this can be done in the fall in connection with planting by scraping away the upper 2 or 3 inches of soil. Such scalping procedure removes dormant weed seeds as well as germinated seedlings, obviating the otherwise necessary return to the area to remove weeds the following spring.

Reseeding trials on mountain meadows of central Idaho

Although the extensive meadows in the subalpine parts of the Boise and Challis National Forests now produce more forage per acre than other forest types, most of them are only in fair or poor condition. The cover is predominantly perennial weeds, and these, like the associated grasses, mature and dry soon after the middle of the summer. The appearance of these meadows suggests that the quantity and quality of forage yields can be improved by artificial measures.

Pilot plantings were made in 1949 to investigate the reseeding possibilities on such ranges. In Bear Valley on the Boise National Forest the planting sites were of two types. The first was on poor, gravelly soil dominated by bush cinquefoil with an understory of perennial grasses and weeds. Sod was loose, open, and rather easily broken. The second site, on a deep sandy loam underlain by coarse sand and gravel, was dominated by danthonia and asters which formed a tight sod. On this meadow it was necessary to work the seedbed several times with a heavy offset disk-harrow after the sod had been broken with a moldboard plow. The cover after seeding was predominantly timothy, alsike clover, and orchardgrass. Plots were protected from grazing the first two growing seasons.

Herbage yields in 1951 of reseeded and comparable nonreseeded plots on both sites are shown in the following tabulation:

Site condition	Reseeded meadow	Native meadow
	Lbs./acre (green weight)	
Gravelly soils, bush cinquefoil-weed-grass	4,624	2,100
Sandy loam soils, weed-grass	14,384	3,180

Results of small-plot trials made concurrently with the pilot plantings in Bear Valley indicate that the rate of winterkill is high among September plantings because of their emergence in the fall. October plantings did not germinate until the next spring and consequently there was a better rate of survival in the initial stands.

Of several grass and legume species tested on various meadow types in Bear Valley on the Boise National Forest and at Cape Horn Guard Station on the Challis National Forest, the following species were observed to yield the greatest amounts of herbage: meadow fescue, timothy, meadow foxtail, smooth brome (Manchar strain), orchardgrass, intermediate wheatgrass, slender wheatgrass, redtop, reed canarygrass, and Canada wildrye.

On the better sites the first three of these species yielded more than 7,500 pounds of herbage per acre (green weight); the others produced between 5,000 and 7,500 pounds per acre. Timothy, the first to become dry, remained green about 2 weeks longer than species of the native cover. Of the others some had only partly dried in late October.

Cattle that were permitted to graze these plots at the end of the second growing season showed a preference for reed canarygrass, redtop, and orchardgrass among the high-yielding species and for alsike and ladino clover, alfalfa, and birdsfoot trefoil among the legumes. Kentucky bluegrass, tall oatgrass, and Russian wildrye were also shown to be very palatable, although not among the high producers. Cattle showed least preference for mountain brome and meadow fescue.

Reseeding research in Nevada

Research in artificial revegetation in Nevada has been under way since 1935. The program has included studies in species adaptability, methods of planting, site factors, and forage utilization, as well as cooperative and demonstrational plantings. Approximately 100 species have been tried to date. Study plots have been established in three of the most important vegetal types within the state. Most work has been done in the sagebrush type, with attention recently being focused on the salt-desert brush type. Considerable work has also been done in the mountain brush type.

Reseeding in the big sagebrush type.--There has been a definite need for knowledge of reseeding in the sagebrush type. Past grazing has in many instances reduced desirable native plants and made reseeding imperative not only for increased forage but for soil stabilization and erosion control. Plots near Paradise Valley, Wells, Elko, Reno, Vya, Winnemucca, Ely, and Mountain City have shown that crested wheatgrass is most suitable for reseeding in this type. More recent studies indicate that the following species also offer promise: intermediate wheatgrass, pubescent wheatgrass, bearded bluebunch wheatgrass, bulbous bluegrass, tall wheatgrass, and Russian wildrye.

Artificial revegetation is of great importance in the sagebrush type because natural revegetation is slow under good management or even complete protection. Reseeding is made difficult, however, by the great numbers of rabbits usually found in the type throughout Nevada. The rabbits converge on reseeded areas, and in some instances, keep the grass seedlings grazed almost to the ground level. It was noted in 1951 that many reseeded plots had been severely grazed by rabbits.

Reseeding in the salt-desert shrub type.--Because of the spread of halogeton in the salt-desert shrub type in Nevada, more attention has recently been directed toward the problems of reseeding in this type. Study plots have been established near Ely, Ruth, and McGill. A wide variety of species was tried on these plots. While these studies are far from completion and the final results cannot be predicted accurately, species which showed some promise in 1951 of becoming established included: Indian ricegrass, crested wheatgrass, yellow sweetclover, tall wheatgrass, Russian wildrye, and pubescent wheatgrass.

Continued work is necessary in this zone because of the great need for artificial revegetation and the rigors of the site. In addition to the grasses, native and introduced shrubs will also be tested.

Reseeding at higher elevations.--Because of the importance of mountain ranges both as watershed areas and as producers of summer forage they have recently been given more study. Study plots on such ranges (chiefly within mountain brush) are located near Paradise Valley, Wells, Tonopah, McGill, Ely, Baker, and Currant. A greater number of species has been tried on these plots because soil and moisture conditions are more favorable. Past studies have indicated that the following species were adaptable in this zone: bearded wheatgrass, crested wheatgrass, mountain brome, and blue wildrye. Other species giving some indication of successful establishment on the basis of investigations during 1951 include: intermediate wheatgrass, pubescent wheatgrass, Russian wildrye, tall wheatgrass, orchardgrass, and smooth brome.

For the purpose of studying methods of reseeding higher mountain slopes in the aspen zone, studies were recently established near Ely and near the Pole Creek Guard Station. Preliminary data indicate that the following species will be successful: tall oatgrass, pubescent wheatgrass, intermediate wheatgrass, and creeping wildrye.

Additional research in revegetation is needed on all mountain sites. The importance of holding soil in place is paramount. Additional species need to be studied, particularly shrub and browse species suitable for winter feed for big game. Studies are being started on Mount Rose near Reno to fill this need.

METHODS OF REMOVING COMPETITION

Brush control.--Studies of means to control undesirable shrub species are being continued. These undesirables invade ranges which have a history of heavy past use or which have been disturbed. Several methods of mechanical control, chemical control, and a combination of mechanical and chemical control were tested in 1951.

Mechanical equipment given further trial during 1951 consisted of a Noble plow and a brush beater. The Noble plow has a large V-shaped blade which is pulled at variable depths under the ground surface. Sometimes called a "root plane," it can be adjusted to cut roots just below their crowns. This devide has proved very effective in controlling rubber rabbitbrush (Chrysothamnus nauseosus) in deep, rock-free soils. It is, however, fairly expensive to purchase and operate. The plow was tried on the Dixie National Forest near Widtsoe, Utah, with very encouraging results.

The brush beater was given considerable testing in 1951. The hard, forged-steel flails of this device strike the shrubs with thousands of blows a minute. This shreds the brush, leaving a layer of litter evenly distributed over the soil surface. Past trials have indicated that big sagebrush (Artemisia tridentata) can be killed by such a treatment. Trials on a 400-acre tract within the Minidoka National Forest indicate that this implement can be used rather generally for sagebrush control where terrain is favorable. Areas strewn with rocks or boulders would result in much breakage of equipment unless extreme care were exercised. The beater kills the brush and leaves a firm seedbed ideal for drilling grass. In a reseeded stand or where there is grass in a native stand, removal of the brush and release from competition enables grass to respond with larger yields. Rabbitbrush, however, cannot be controlled by such beating due to its ability to sprout from the root crown.

Chemical control of brush was subjected to further study. It has become apparent that the most troublesome species in the Intermountain area are very resistant to chemical control. Both big sagebrush and rubber rabbitbrush require rather heavy and costly application of 2,4-D and 2,4,5-T for a complete or satisfactory kill. Tests were made in 1951 involving the use of chemicals on rabbitbrush which had previously been burned. The lush young regrowth was sprayed with varying amounts and combinations of chemicals. Preliminary observations indicated that spraying after burning may be an effective method of controlling rubber rabbitbrush.

Combined mechanical and chemical treatment was studied on one area on the Dixie National Forest to determine the effect of chemicals on rubber rabbitbrush after treatment by the brush beater. The shrubs were beaten with the brush beater in the early spring. Later in the spring, the regrowth from this area was sprayed with 2,4-D and 2,4,5-T. This study will be continued. Preliminary observations indicate a promising degree of control.

GRAZING TRIALS ON RESEEDED RANGE

Grazing of cattle on crested wheatgrass.--Studies have been conducted at Benmore, Utah, for 5 years to determine the correct intensity and best method for grazing crested wheatgrass. Results of these studies are summarized below.

Twenty-four 100-acre pastures are grazed by cattle for approximately 60 days in the spring and between 40 and 50 days in the fall when regrowth is adequate. Four methods of grazing are practiced: (1) rotation, with cattle being shifted periodically among three sections of the pasture, so as to graze each section twice during the season; (2) continuous; (3) 10-day deferred; and (4) removed 10 days early. Each of these methods is conducted at three intensities of utilization: light, 45 to 50 percent; moderate, 60 to 70 percent; and heavy, 75 to 85 percent. All treatments are replicated. The pastures were grazed uniformly at a moderate intensity during the spring of 1947 in an attempt to provide an equalized basis for later comparison. Since then they have been grazed as outlined.

Average daily gains of cattle more than 6 months old during the 1951 season were 2.91, 2.68, and 1.65 pounds per head for light, moderate, and heavy grazing. These figures conform to the 4-year averages for these intensities of use (table 10). These 4-year averages show that mature animals made the greatest daily gains in pastures from which they were removed 10 days early and least in rotation pastures.

Table 10.--Average daily gains made by cattle during four spring seasons of grazing at three intensities and under four methods, Benmore, Utah, 1948-51

Method of grazing	Intensity of grazing		
	Light	Moderate	Heavy
Rotation	2.63	2.51	1.86
Continuous	2.88	2.70	1.97
10-day deferred	2.81	2.66	2.12
10-day short	3.10	2.91	2.23
Average	2.86	2.70	2.05

Table 11 shows that method of grazing has had little influence on daily calf gains, but that calves made slightly less daily gain on pastures grazed at a heavy intensity than at either a moderate or light intensity. In 1951 the gains per acre for cattle more than 6 months old were 28, 33, and 25 pounds, respectively, for light, moderate, and heavy grazing. When the calf gains were added, the gains per acre become 39, 48, and 43 pounds, respectively. This is the first year that gain per acre for heavily grazed pastures has fallen below that for either of the other intensities. This probably reflects the damaging effects of continued heavy grazing on forage production. As yet, no definite trends in gain per acre have resulted from method of grazing. The average gain for all treatments over the past 4 years is 44 pounds per acre when about half the animals are supporting calves.

Table 11.--Average daily gains made by calves during four spring seasons of grazing at three intensities and under four methods, Benmore, Utah, 1948-51

Method of grazing	Intensity of grazing		
	Light	Moderate	Heavy
Rotation	1.87	1.84	1.69
Continuous	1.96	1.92	1.80
10-day deferred	1.84	1.91	1.72
10-day short	1.86	1.92	1.77
Average	1.88	1.90	1.75

During 1951 the average utilizations of 52.3, 65.5, and 81.2 percent for light, moderate, and heavy grazing, respectively, were close to the planned intensities of 50, 65, and 80 percent use. The dry weight yields of crested wheatgrass on pastures used for light, moderate, and heavy grazing were 638, 644, and 623 pounds per acre, respectively, compared with 496, 470, and 533 pounds per acre in 1950.

More seedlings of crested wheatgrass appeared in 1951 than in any year since the study began. This resulted in increases in total number of plants from 1950 of 29, 12, and 5 percent for light, moderate, and heavy grazing, respectively. Up to 1950 there had been a 9 percent increase in number of plants for all pastures regardless of grazing treatment.

Density of crested wheatgrass has increased on the average 54 percent for all pastures in the last 4 years. This is partly because crested wheatgrass has filled in "islands" of cheatgrass, but mainly because individual plants have increased in size. Thus far, neither method nor intensity of grazing has had a discernible influence on increase in density.

Under all treatments both rabbitbrush and sagebrush have nearly doubled in herbage yield, principally because of an increase in size of plants. Neither species, however, has been observed to invade a vigorous, full stand of crested wheatgrass, although young brush plants of both species are invading in places where there is less than a full stand of crested wheatgrass and in some very heavily grazed spots where grass vigor has been greatly reduced. Rabbitbrush is now present on 19 percent of the permanent plots used for taking data on vegetation, whereas 4 years ago it was found on only 14 percent. Sagebrush is now present on 8 percent of the plots compared to 6 percent 4 years ago.

Grazing of sheep on crested wheatgrass.--Since 1944 spring grazing with ewes and lambs at three intensities--light (60 percent), moderate (70 percent), and heavy (90 percent)--has been applied to seeded pastures in which crested wheatgrass is the predominating species. The six pastures involved are near Ephraim, Utah. Two pastures are grazed at each intensity, but grazing is started on one pasture of each treatment when crested wheatgrass is 2 or 3 inches high (early stage), and on the other about 2 weeks later when the grass is 4 or 5 inches high (stage of vegetative readiness). Spring grazing closes on all pastures about the same date. April 14 has been the average starting date for early grazing; April 27, for grazing based on vegetative readiness; and May 25, the average spring closing date. Pastures have been grazed in the fall so as not to alter effects of the spring grazing treatment. In 1951 and 1950 there was no fall grazing because summers and falls were too dry for any regrowth.

During the 7-year period of study, the starting date of spring grazing has made no evident difference in response of grass, although ewes and lambs made slightly higher gains per day in the early pastures than they did in the vegetative readiness pastures. In 1951 differences became evident between the heavy versus light and moderate treatments both in vegetation and production of animals. No important differences have yet become apparent between light and moderate grazing treatments.

Great increase of Russianthistle under heavy grazing is one of the most evident signs of loss of vigor in the crested wheatgrass. In 1951, yields of Russianthistle were nearly five times greater and plant numbers were about eight times greater in the heavily grazed pastures than in the light and moderately grazed pastures, as shown in the following tabulation:

	Russianthistle			
Grazing treatment	Plant numbers per sq. ft.		Herbage production per acre	
			Pounds	
Light	0.84	1/6	80.34	1/4
Moderate	.48	1/11	67.30	1/5
Heavy	5.26		364.24	

These obvious differences were slow to develop. During the first years crested wheatgrass plants under heavy grazing showed some loss of vigor by lowered yield in early spring, but yields were largely made up later in the year. Other early indications of low vigor were reduced stature and tendency for foliage to spread horizontally along the ground. In 1951, after 7 years of heavy grazing, the centers of crested wheatgrass clumps were dead and were breaking up badly. In places Russianthistle was growing out of the grass clumps.

During the first 3 years of treatment, the heavily grazed pastures furnished 110 more sheep days per acre in the spring than those moderately grazed. In the next 4 years the moderately grazed pastures furnished 7 sheep days per acre more in the spring than those heavily grazed. Average numbers of sheep days per acre during the 5 years of fall grazing on the light, moderate, and heavy spring-grazed pastures were 51, 42, and 27 days, respectively. When sheep days in the fall were combined with sheep days in the spring there were only 25 days more use under heavy grazing than under moderate grazing, an advantage built up in the early years of the study.

Lambs in pastures grazed at moderate and heavy intensities made identical average gains per day of 0.57 pound for the 6-year period that weights have been recorded (table 12). Lambs in the lightly grazed pastures had the highest rate of gain in four of the 6 years and had an average gain per day of 0.63 pound. Average lamb gain for all intensities of use was more than 0.50 pound per day in all years and reached a high of 0.70 pound per day in 1951. In past years, more lamb pounds per acre have been taken from the heavily grazed pastures than from the others. Average yearly lamb gain per acre was 35.4 pounds for heavy, 32.0 for moderate, and 28.2 for light. However, in 1951 more lamb pounds were taken from pastures grazed at light and moderate intensity than from those heavily grazed, the figures being 24.3, 26.3, and 22.7 respectively.

Table 12.--Average gain per day (in pounds) for lambs under three intensities of grazing

Year	Grazing intensity		
	Light	Moderate	Heavy
1946	0.57	0.51	0.56
1947	.53	.48	.53
1948	.62	.66	.53
1949	.64	.49	.53
1950	.72	.63	.70
1951	.72	.71	.67
Average	.63	.57	.57

Mother ewe gains for the 6-year period averaged 0.18, 0.30, and 0.08 pound per day (8.22, 15.73, and 5.65 pounds per year) under light, moderate, and heavy grazing. The lower ewe gains for moderate and heavy grazing are reflected in the slightly higher lamb gains per day.

Crested wheatgrass compared to winter rye.--Ewes and lambs have grazed comparable winter rye and crested wheatgrass pastures near Ephraim, Utah, in the spring for 3- to 5-week periods in late April and May since 1943. When there is sufficient regrowth, pastures are also grazed in the fall. Winter rye is an annual and thus depends on some seed maturing for maintenance of the stand.

For the first 2 years the 5.8-acre rye pasture was compared to a 6-acre crested wheatgrass pasture. In 1944 the crested wheatgrass pasture was enlarged and divided into six 1½-acre pastures. Three of these pastures have been grazed concurrently in the spring with the rye pasture and their composite use has been compared with that of the rye pasture since that time.

Gains and grazing use obtained have been very similar on the two types of forage as shown in tables 13 and 14. Lambs averaged slightly over 1/2-pound daily gain and ewes averaged about 1/4-pound daily gain on both forage types. Lambs and ewes in the rye pasture averaged slightly more gain than those in the crested wheatgrass but this advantage has not been consistent.

Both forage types furnished an average of 4.4 sheep months grazing per acre during the spring period. Crested wheatgrass has furnished an average of 0.3 sheep month more grazing than rye for the combined spring-fall periods. Crested wheatgrass pastures were grazed again in the fall except in 1950 and 1951; the rye pasture has furnished fall grazing in only 3 years.

Table 13.--Spring gains per day by lamb and mother ewes on crested wheatgrass and rye pastures, 1943-51

Year	Lambs		Ewes	
	Crested wheatgrass	Rye	Crested wheatgrass	Rye
		Pounds		
1943	0.50	0.67	0.48	0.52
1944	.48	.63	.47	.50
1945	.51	.49	--	--
1946	.51	.56	.41	.17
1947	.42	.36	--	.16
1948	.58	.55	.19	.38
1949	.48	.54	.23	.29
1950	.72	.75	.24	.09
1951	.70	.66	.22	.44
Average	.54	.58	.25	.30

Table 14.--Sheep months per acre from crested wheatgrass and rye pastures, 1943-51

Year	Crested wheatgrass			Rye		
	Spring	Fall	Total	Spring	Fall	Total
1943	3.6	1.3	4.9	5.7	0	5.7
1944	5.0	2.2	7.2	5.1	3.1	8.2
1945	6.5	1.7	8.2	6.5	2.3	8.8
1946	4.3	1.2	5.5	2.9	0	2.9
1947	5.0	2.0	7.0	4.9	1	6.7
1948	4.8	.9	5.7	3.9	0	3.9
1949	4.3	.8	5.1	3.4	0	3.4
1950	3.5	--	3.5	3.6	0	3.6
1951	2.5	--	2.5	3.7	0	3.7
Average	4.4	1.1	5.5	4.4	.8	5.2

With proper management rye pastures can be maintained for several years even when the annual precipitation is no more than 10 inches. To insure continuing stands, however, livestock must be removed from the rye in late May or early June to allow it time to mature seed. When grazed in the fall, care must be taken to see that enough seed has fallen on the ground for the next year's crop. With only 10 inches of annual precipitation it is usually necessary to disk in the fall to cover the seed.

Once established, crested wheatgrass is more dependable than rye. Crested wheatgrass also furnishes good grazing approximately two weeks earlier in the spring than rye and no additional expense is incurred to keep it in production. These factors, together with the better grazing furnished in the fall establishes crested wheatgrass as a superior pasture for spring-fall ranges.

PLANT BREEDING

At the Great Basin Research Center new and promising strains of grasses and legumes are tested in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering, the Soil Conservation Service, and the state experiment station. All past work is under detailed analysis and a report will be released during 1952 to cooperators and others interested in current results of these trials.

Strain tests of smooth brome.--Because of availability of seed and wide adaptability, smooth brome is the most generally used grass for mountain ranges. During the past several years northern and southern strains have been tested in the mountain brush, aspen, and subalpine zones. The tabulation below shows yields of representative northern and southern strains during 1951, 7 years after establishment, at three different elevational sites.

Strain	Mountain brush site (7,100 ft.)	Aspen site (8,800 ft.)	Subalpine site (10,000 ft.)
	Pounds per acre (green weight)		
Northern (Kellers-B-12)	1,656	8,302	7,250
Southern (Lincoln)	2,750	8,222	5,100

On the basis of these results, it is suggested that a southern source of smooth brome be used for seeding on mountain brush ranges. In the aspen type, it probably would be well to employ a mixture, and on subalpine ranges, seed from a northern source would probably be best.

PROBLEMS IN HALOGETON CONTROL

Halogeton, a stock-poisoning plant of aggressive habit, has invaded many ranges in the Intermountain region, particularly the winter and spring-fall ranges of Utah, Idaho, and Nevada. Recently much interest has been directed toward this plant and range managers and livestock men are much concerned with its control. Many varied opinions have been expressed about the plant's poisonous qualities, livestock losses, and methods of control.

In considering the problems arising from the spread of halogeton and those involved in controlling it, some knowledge of its history, present areas of occupancy, poisonous qualities, and other characteristics is essential. The following summary, which presents some of this necessary background information, has been compiled from observations of personnel of this Station, as well as from reports released by the University of Idaho, the Utah State Agricultural College, and the University of Nevada. All of these institutions are actively engaged in various phases of work to combat the weed.

History.--According to W. A. Dayton, halogeton was probably first collected in Russia by Christian Friedrich Stephan in the 18th or 19th century. This first collection was labeled Salsola glomerata but the name was never published. In 1829 C. A. Myers published the name Halogeton glomeratus at which time he stated that the species was abundant on saline soils of the deserts of southwestern Siberia and northeastern China. In 1934 Ulbrich listed the plant's range as extending from the Ural Mountains and Caspian Sea over the desert steppes of southern Russia to the desert wastes of southwestern China and Tibet. The genus Halogeton includes 12 species of which 5 are found mainly in Siberia, 3 in southern Russia and Turkestan, and one each in the Mediterranean region, Algeria, Arabia, and Iran.

Halogeton was first collected in the United States in 1934 along U. S. Highway 40 near Wells, Nevada by Dr. Ben Stahmann, then with the Intermountain Forest and Range Experiment Station. It was found on a small area where the native vegetation had been destroyed.

Halogeton spread rapidly and by 1940 it had reached into Idaho and Utah. At present it covers extensive areas in northern Nevada, southern Idaho, and northern Utah with outlying stringers as far south as Ely, Nevada and Thermo, Utah along the Union Pacific Railroad tracks. It has also been reported in eastern Utah, southwestern Montana, western Wyoming, southeastern Oregon, and eastern California near Honey Lake in Lassen County. Recently it was found near Concord in Contra Costa County in the San Francisco Bay region.

Factors favoring spread of halogeton.--The heaviest infestations of halogeton are found in places where the native vegetation has been depleted or destroyed. In southern Idaho near Malta, halogeton has invaded large tracts of shadscale range. For many years these ranges were heavily grazed and the better forage species were damaged or destroyed by sheep and cattle. A recent survey indicates that during the last several years a species of snout moth has destroyed the shadscale on more than 20,000 acres of this already-weakened range in the Raft River Valley near Malta. Halogeton is rapidly invading these depleted ranges and now forms dense stands on many areas. It appears that whenever the native vegetation is reduced by heavy grazing, or when it is destroyed by insects or mechanical equipment, conditions are created for halogeton invasion.

Halogeton produces large quantities of viable seed. The plant flowers in June and July and seed is disseminated between the months of September and November. The seeds fall to the ground and by means of small winged bracts are easily blown along the ground. Others are carried long distances by vehicles and animals. Halogeton seed germinates in the late spring; the plants grow rapidly.

Road maintenance equipment used to clear weeds along highways, to clear snow, or to grade shoulders has probably helped to spread halogeton many miles in a single year. Highway grades, cuts, and borrow pits are often heavily infested with halogeton a year or two after their construction. Frequently spots of halogeton are found on isolated stretches of highway. A year or two later the entire roadside may be heavily infested.

Railroad rights-of-way also provide an easy and rapid lane of migration. The infestation near Thermo, Utah, along the railroad is an example. This is a hundred miles or more from other known infestations.

Sheep trails, shearing corrals, and bedding grounds also provide favorite places for invasion and spread of halogeton. On an area of winter range in Beaver County a localized infestation of halogeton occurs 60 or 70 miles from other known spots of halogeton. Seed may have been picked up along the fall sheep trail and transported by sheep or by camp equipment.

Although the initial and most rapid spread of halogeton is usually along roads and on overgrazed and depleted range, it is frequently found scattered among the native vegetation in shadscale and saltsage ranges still in fair condition. Halogeton is well adapted to the saline soils of the semiarid winter ranges of the Intermountain region. Its root system penetrates the soil to a depth of 2 or 3 feet thus enabling the plant to remain green and thrifty throughout summers when many of the native species become dry and almost dormant.

Poisonous properties and livestock losses.--The poisonous constituents of the plant are soluble sodium and calcium oxalates. In the fall the oxalate content is about 20 percent. At this time about one pound of air-dry herbage is sufficient to kill sheep. During the winter the oxalates are leached out of the plants and in late winter the oxalate content is often only 4 percent. At present no antidote is known. The only method of control is therefore to prevent the animals from eating the plant.

A few cases of heavy sheep losses from halogeton poisoning have been reported. The heaviest loss occurred in the Raft River Valley in 1945 when a single stockman lost about 1,600 head. Except for this case losses reported have been light, probably because sheepmen have been reluctant to put their sheep on areas where halogeton was abundant. This was the case in the Raft River Valley.

There is considerable evidence that sheep are not poisoned by halogeton on ranges where ample native forage is available. Generally halogeton is not very palatable and sheep do not utilize the species much except when they are extremely hungry or when other vegetation is not available.

Although some cattle losses from halogeton have been reported, few if any have been verified. The relation of halogeton to game losses, especially the death loss in antelope, is not presently known.

Methods of controlling halogeton.--The rehabilitation of depleted ranges is probably the most urgently needed aspect of halogeton control. As has been pointed out, halogeton invades native vegetation that has been seriously disturbed or weakened. Procedures which help to restore or improve the plant cover tend to reduce the area in which halogeton can grow. Many studies in the past have shown that a system of proper management is a primary requisite for improvement of the plant cover. Proper management may include several practices or combinations of practices. Proper rate of stocking so that the number of livestock grazing a given area do not exceed the carrying capacity of that area is important. Natural revegetation is encouraged when the forage is not overgrazed, when it is grazed at proper season, or if the vegetation is protected from grazing for a period to allow recovery and reproduction.

Although halogeton is found over a sizable territory, the infestation is far from being a continuous stand. In many places only spotty stands exist, and range lands adjacent to these sore spots, while not in optimum condition, are still capable of resisting invasion. These ranges must be carefully managed to prevent any deterioration which might weaken the present stand and thus make it susceptible to the encroachment of halogeton.

On ranges where desirable species have been killed or depleted, artificial revegetation, in many cases, can provide cover to keep out invading species. In some areas it has been demonstrated that crested wheatgrass holds the site and prevents the establishment of halogeton. Continued research is being done to find methods and species suitable for revegetating the somewhat saline soils of the salt-desert shrub type where halogeton is most abundant.

Attempts were made to control roadside stands of halogeton by mechanical means shortly after its poisonous properties were discovered. It was found that this disturbance opened the site for further invasion. Disking a site repeatedly killed the halogeton but the disturbed area, unless planted to an agressive species, was open to infestation by halogeton again.

Chemical control was adopted early in the fight against halogeton. Tests have shown that while the plant is relatively easy to kill, the characteristic of delayed germination enables plants to start growth over a long period. Spraying to prevent seed formation by some of the earliest plants would miss those plants developing from later germinating seed. Both 2,4-D and 2,4,5-T are effective against halogeton during the early growing season. The fact that these sprays also kill other vegetation, thus further depleting the vegetal cover, suggests that their use may be limited to special situations.

Halogeton problems that need further study.--Considerable research is necessary before all the obstacles to reseeding in the salt-desert shrub type are overcome. While a beginning has been made, more knowledge is needed about species that are adaptable to the saline soils and the low precipitation usually encountered. Both grasses and shrubs are needed. If the reseeded areas will eventually be used for winter grazing, it would be desirable to have shrubs or browse plants reseeded. Additional studies are needed to find which of the native shrubs are suitable for this purpose. Further work also needs to be done on shrubs from other countries which may prove to be of value on the salt-desert shrub type. Since most shrubs are slow growing, grasses must be planted when cover is needed quickly. Both local and foreign grasses need further testing to prove their fitness for such a habitat.

Problems of management of reseeded shrubs and grasses need to be studied and a system of use developed that would maintain the stand and prevent reinvasion of halogeton. More work is needed to learn how to utilize ranges with safety where halogeton is already present. Knowledge is needed as to whether some plants make the presence of halogeton more dangerous and whether others might nullify the threat that halogeton poses.

Also needed is information on just how to manage ranges where halogeton exists so it can be reduced or eliminated. It is necessary to know the minimum plant cover necessary for halogeton control and whether some perennials, native or introduced, are more efficient than others in competing with halogeton.

Additional work is needed concerning the toxic properties of halogeton. Also meriting study are the effects of various soil types on the plant's poisonous properties and whether minerals can be fed to minimize or counteract the poison. Any medicines or antidotes that may be administered to stricken animals to aid recovery should be investigated. Studies should also be done to learn if immunity to the poison can be acquired and, if so, what effect the eating of halogeton will have on the offspring of recovered females. Will consumption of halogeton affect the quality of flesh of animals slaughtered for human consumption? Are wildlife species such as deer and antelope affected by halogeton? All these and other unanswered or partially answered questions need investigation and clarification before we can feel easy about halogeton.

PROGRAM FOR 1952

Species adaptability

1. Analyze data and prepare report on species adaptability investigation.

2. Continue studies to determine suitable species for seeding desert ranges in Nevada and the Colorado River Basin.

3. Continue tests of perennials suitable for replacing cheatgrass and other annuals on granitic slopes in Idaho and Nevada.

4. Initiate studies to determine suitable species for reseeding burns in the timber types in Idaho and Wyoming.

5. Continue studies of browse species suitable for big game winter ranges in Utah, Idaho, and Nevada.

6. Expand range plot tests and pilot plantings for observation under grazing of species which have shown promise for range reseeding.

Methods of removing competition and planting

1. Continue testing commercial machinery for removal of competition and for tilling and seeding operations.

2. Continue studies of sagebrush and rabbitbrush control by chemical means.

3. Continue studies of methods of seeding bitterbrush and other shrubs for winter game range.

4. Continue studies of controlling tarweed and seeding in tarweed areas.

5. Continue search for methods of seeding granitic slopes.

Grazing trials on reseeded areas

1. Prepare a report on results of grazing crested wheatgrass at Benmore, Utah, in cooperation with Utah State Agricultural College.

2. Summarize data on grazing reseeded areas in Nevada.

3. Summarize and report on effects of grazing sheep on crested wheatgrass at three different intensities.

4. Summarize and report on 9 years' comparative grazing of crested wheatgrass and rye.

Site factors

1. Summarize data correlating crested wheatgrass yields with measurable site factors.

2. Initiate studies of the effect of commercial fertilizers on the productivity of mountain meadows, both native and reseeded.

Plant breeding

1. Enter new accessions or species furnished by cooperators or collected by the Intermountain Station into adaptability trials in various vegetal zones.

Halogeton control

1. Continue search for species to control and replace halogeton on arid saline sites.

ECONOMICS

RANGE ECONOMICS

Forage, wildlife, recreation, water, and timber are the wild-land resources with which multiple use management of the national forests is concerned. To achieve the management goal of maximum sustained human welfare these resources must be used with full understanding of the physical, biological, and economic forces affecting them. To illustrate these forces, one may note that the physical characteristics of soil are important in determining the limits of production of a land unit through their effect on the biological factor--the plant cover. The economic needs of the human community and availability of economic resources, including labor, capital, and management skill, determine which of the possible plant cover types shall be favored. These economic factors may also circumscribe the production level to which plant cover development shall be encouraged, the relative amount of resources to be invested in developmental work, and the use which will be made of the plant cover and its underlying soil.

Land management agencies are constantly engaged in maintaining and improving the productivity of their lands and in adjusting various production activities to fit multiple use needs. Adjustments in land uses such as those made for the prevention or alleviation of erosion, sedimentation, and flood damage require the restoration of the physical conditions of the site so that it will support the desired plant cover. Measures to be taken for the restoration work are guided by economic factors. Many other management adjustments, such as the reserving of timber growing land for recreational use, are almost exclusively economic, involving little change in the physical or biological situation.

Land users and administrators need information on quantities and money values of resources in order to understand and plan the best pattern of multiple use. Much careful work is needed to make available usable figures, to unravel their complexities, and to present them in a way that will best serve the need.

The planning of Federal river basin development programs requires economic analysis including evaluation of benefits and costs of wild-land management. Appraisals of social, intangible, and indirect returns and costs, which are extremely important on wild lands, are needed but satisfactory procedures have not yet been worked out.

In all these fields the Forest Service economics research organization can be of service.

Resource inventory and analysis

The resource information mentioned in the 1950 annual report has been maintained in current status insofar as figures are available. The beginning made in this region on the local phase of the nation-wide forest survey and the recent addition of a forest survey man to the Station staff promise further progress in assembling better data on the timber resource. The status of the forest survey work is summarized in a separate section of this annual report.

Some exploratory work was begun this year to provide a basis for comparison of various national forest resource values. A comparison of values may be secured by estimating what each resource contributes to local business activity. One measure of this contribution may be the money received for the products derived from the resource when sold at the point ending the initial processing. Thus the livestock owner sells meat and wool and from the money received he pays salaries, rentals and grazing fees, interest on borrowed money, and local bills such as those for supplies and equipment. He also may invest some of the proceeds in local business enterprises. Receipts from the sale of products arising from the use of national forest resources beyond the point of initial processing are less easily estimated and often accrue to localities remote from the forest-dependent communities.

The returns to first processors of national forest products do not show the contributions of the resources to secondary and subsequent processing industries, nor do they indicate the value to the users of the recreation facilities, scenery, and wildlife. These figures likewise will not answer questions, for example, as to which is preferable: a dollar of income from domestic livestock grazing or a dollar from a competing use such as wildlife. It is believed, however, that a compilation of information on resource values, if established on a sound basis and refined as better data become available, will contribute to an improved understanding of multiple use management. The better understanding will, in turn, aid in achieving the management goal of maximum sustained human welfare.

Tentative estimates of the national forest contribution to the business activity within Forest Service Region 4 (Utah, Nevada, southern Idaho, western Wyoming, and very small areas of California and Colorado) are here made for domestic livestock forage, wildlife, and recreation.

The 1,179,479 animal unit months of cattle forage harvested from the national forests of this region estimated on the basis of 1949 money income, contributed approximately $6,192,000 to business activity. The 3,543,673 animal-unit-months of sheep forage brought ranchers about $18,179,000, most of which then probably went into local business channels. The total gross receipts from national forest domestic livestock forage were therefore $24,371,000 on the basis of these tentative estimates.

Forest Service reports for 1950 show that 476,000 hunters and fishermen used something like 2,300,000 man days in harvesting 76,000 mule deer, 7,300 elk, and unestimated numbers of other game and fish from the national forests. If each sportsman is assumed to have spent an average of $50.00 in his hunting and fishing activity the wildlife resource affected business in this region by the amount of $24,000,000.

Almost the entire national forest land area has some recreational value. Of special recreational importance are the wilderness reservations, comprising 2,644,000 acres, and the campground, picnic, summer home, and similar intensive developments which total 19,200 acres. During 1950 approximately 4,073,000 recreational visits were estimated for this region, most of which probably involved little expense to the visitor. The enjoyment of the relatively "free" national forests cannot be measured by the money expended by recreationists, and the effect on business in the region is incidental and perhaps of minor consequence. If, however, an expenditure of 15 cents per visit is assumed (some 1946 estimates in Colorado used 10 cents), national forest recreation brought $611,000 to local tradesmen during the year 1950.

An estimated 24,900,000 acre feet of water flow off the national forests of this region annually. The effect of management in maintaining water quality and sustained flow and in preventing flood damage and sedimentation is difficult to determine in monetary terms. Data are not presently available for making any accepatable estimate of water values, but technicians generally assume that they exceed those of any other wild-land resource.

One irrigation development project, analyzed in this region in 1949, showed direct benefits from irrigation water to be an estimated $10.60 per acre-foot annually. Whether this value is typical for Forest Service Region 4 is unknown, and, consequently, the figure cannot be applied to the total water yield to give any estimate that can be compared to the others here made.

Values in multiple use management

A project was started last year to develop economic guides for the wild-land administrator faced with the task of making adjustments between various land uses. Informal discussions have been held with state and Federal technicians and a study plan and outline have been developed. Some progress has been made in development of the theoretical basis for the study and in exploration of literature.

Extending economics concepts

The exchange of ideas with other research workers and wild-land technicians has been accomplished through discussions, participation in activities of the Intermountain section of the Society of American Foresters, and through a technical seminar program at this Station. Greater participation is planned for the coming year in activities of organizations interested in economics research.

The Division of Range Economics has been of some service in flood control planning work, particularly for the Columbia River basin area. Considerable assistance was given to Forest Service economics investigations in the field and in the Washington office. Technical aid has also been freely given, insofar as time and opportunities permitted, to the review of research manuscripts involving economics material.

Program for 1952

The first phase of the study concerned with developing economic guides to wild-land administrators in adjusting land uses is scheduled for completion during the year. This phase covers adjustments between livestock forage and watershed uses. A second phase, covering livestock forage and wildlife uses, will be started when the first project has been completed.

FOREST SURVEY

On October 1, 1951, a Forest Survey office was established at this Station with one man assigned to it. Major responsibility for conducting the Forest Survey in this Region has been assigned to the Northern Rocky Mountain Forest and Range Experiment Station. The office at this Station will function primarily in a liaison capacity between the two Stations and Region 4. Forest Survey field work in this Region actually started in May in southern Idaho. By the end of the field season Forest Survey and cooperating crews had completed the type mapping and measurement of sample plots on over two and one-half million acres of land.

The field work of the past season was carried on in two areas. One of these, in Bannock, Madison, and Teton Counties, was of an experimental nature to test survey methods believed to be best adapted to Intermountain conditions and to the funds likely to be available for survey work in the Intermountain area. The second area was on the Boise and Sawtooth National Forests as a part of a cooperative undertaking with the Region 4 Division of Timber Management.

In this latter area, the Region 4 Division of Timber Management is currently carrying on a forest management plan study of the Boise and Payette National Forests lands and adjacent and intermingled lands. To avoid duplication of effort in this area the plan for this study was drawn to meet Forest Survey requirements as well as those of the management plan itself. Forest Survey crews will aid in carrying on the field and office work of the project. A three-way cooperative agreement has been worked out between the Intermountain Forest and Range Experiment Station, the Northern Rocky Mountain Forest and Range Experiment Station, and the Region 4 Division of Timber Management for carrying on the work of both the Forest Survey and the management plan study in this area.

Program for 1952

The work of the Forest Survey in 1952 will be primarily to carry on field work in the Boise-Payette area in collaboration with the management plan study in that area. A census of 1951 lumber production in Nevada will be carried on in cooperation with the California Forest and Range Experiment Station.

FOREST MANAGEMENT RESEARCH

Progress on the installation of the methods-of-cutting study in virgin ponderosa pine has been maintained. During the field season of 1951 the preparatory work covering 16 minor drainage compartments was completed. This included the marking (by paint) of drainage lines; the locating and marking of condition class lines; the traversing of condition class boundaries; the 100 percent cruising of 9 of the condition class areas to determine minimum volumes per acre for each condition class which must be secured before volume to be removed can be determined; the measuring of height and diameter of a suitable number of trees from which to make local volume tables; the mapping of age classes in compartments to be cut by the group selection method; and the establishing of permanent reference points for the condition classes of all 16 minor compartments.

Preliminary analysis of the cruise and height-diameter data has indicated some interesting trends. If it is borne in mind that the condition classes are based on volume per acre (condition class I--under 10,000 f.b.m. per acre; condition class II--10,000 to 20,000 f.b.m. per acre; and condition class III--over 20,000 f.b.m. per acre), the following facts are evident:

1. The percentages of Salman-Bongberg insect risk classes III and IV, both separately and additively, are lowest for condition class I and highest for condition class III.

2. The percentages of Salman-Bongberg insect risk classes I and II, additively, are highest for condition class I and lowest for condition class III.

3. In condition class I, the highest percentage (93.3) of the number of trees is in Keen age class 1.

4. In condition class III, the lowest percentage (15.0) of the number of trees is in Keen age class 2.

5. The average number of trees per acre for condition classes I, II, and III, are 16.6, 18.8, and 22.9, respectively.

6. Considered in the light of Keen classes 3 and 4, the least risk by number of trees per acre is in condition class I (0.5); the most in condition class III (11.4).

7. The total height-diameter curves for the three condition classes suggest a relationship between a given condition class and its corresponding site class.

SEED VIABILITY

Ceanothus velutinus.--C. velutinus, commonly known as snowbrush, a vigorous, woody shrub reaching some 4 feet in height, establishes itself quickly and densely where soil has been greatly disturbed as after forest fires or logging. The plant provides competition for natural and planted seedlings. To learn what treatment, simulating natural conditions would prompt germination, some viability tests were made in which burning, abrading, and no treatment were each employed to test boiled and untreated seed, all lots of which had been previously stratified in moist sand.

While the results have not been completely analyzed, it is obvious that some hot water treatment increases germination but that burning for 45 minutes (with seed buried an inch in moist soil) produced approximately the same result. Average germination of all lots (8.8 percent) and even the highest of any one treatment lot (17.3 percent) is considered low compared to results from other sources applying somewhat similar treatments.

Douglas-fir.--No records of viability for Douglas-fir are available for central Idaho. Germination tests were made under field conditions for seed collected in 1937 and in 1950. Both lots were stored dry in air-tight containers where annual temperatures fluctuated from 30 to 55 degrees F. The 1937 seed showed no germinative capacity; the 1950 seed averaged 78 percent. Both lots were stratified in moist sand for 43 days at from 35 to 40 degrees F. Cutting tests had shown the 1937 seed to be 35 percent sound and the 1950 seed 82 percent. The germinative energy displayed by the 1950 seed is interesting; 71 percent germinated within 11 days after sowing.

Lodgepole pine research.--Toward the end of the year David Tackle, formerly of the California Station was transferred to this Station to begin research studies in lodgepole pine. This was made possible by the cooperation of Administration. His assignment creates an opportunity to explore the potentialities of this species of which there are at least 2.5 billion board feet in the Intermountain region. Since the greater part of this volume and the highest quality is in Wyoming it is probable that work will be focused there at the outset.

PROGRAM FOR 1952

Ponderosa pine.--Main efforts will be centered on the installation of the first replicate of 8 minor drainages of the methods-of-cutting study on the Boise Basin Experimental Forest which will require a full field season. Priority in office work will be given to analysis of data arising from this field work. Incidental and old studies will be analyzed as time permits.

Lodgepole pine.--A problem analysis for lodgepole pine management will be made so that priorities of problems and their location can be selected. This should enable an active research program to be launched in 1953.

FLOOD CONTROL SURVEYS

Flood Control Survey activities of the Station during 1950 consisted mainly of: (1) completion of the flood control phases of comprehensive river basin surveys for the Columbia and the Arkansas-White-Red River Basin; and (2) additional revision of Flood Control Survey reports prepared in previous years for other watersheds.

PROGRESS ON SURVEYS

Columbia River Basin (Comprehensive Agricultural Program)

In addition to participation on committees and subcommittees responsible for the development of specific parts of the survey and the comprehensive report, accomplishments during the year on the flood control phases of the Columbia River Basin Agricultural Program include the following:

1. Assistance to Region 4 of the Forest Service in revision of Project Work Inventories for national forest lands. Joint teams spent a week on each national forest guiding forest personnel in the development of up-to-date and realistic programs for needed improvements. Similar information was obtained for lands administered by the Department of the Interior, for state forest and range lands, and for privately owned forest lands.

2. Investigation of factors affecting snow deposition and rates of melt on 20 forested and 40 open snow courses in the Snake River Basin. Analysis of results and the synthesis of flood hydrographs using the data obtained was begun late in the year.

3. Collection of data on flood and sediment damages and correlation of these with similar information collected by the Soil Conservation Service on private lands.

4. Study of site characteristics, present condition, needed measures, and estimates of future conditions on 21 sample watersheds. Altogether 43 such sample watersheds and two additional block samples have been so studied in 1950 and 1951.

5. Stream channel conditions and the need for structural measures were investigated on 20 sample watersheds.

6. Columbia Basin lands comprising the Snake River Watershed above Lewiston, Idaho, were classified as to ownership and principal land type (forest, range, cultivated, and other). This information was tabulated and summarized by counties.

7. A preliminary draft of a uniform range type map for the Snake River Basin above Lewiston was developed in cooperation with the Soil Conservation Service and Forest Service Region 4.

8. Preliminary drafts of descriptive material, maps, and charts were prepared for the Columbia River Basin Comprehensive Agricultural Program. Physiography, geology, soils, climate, water yield, sedimentation, and erosion are briefly described for the Snake River Watershed above Lewiston (Oregon and Washington portion excepted). Members of the flood control staff also assisted with the preparation of descriptive material for forest and range lands.

Upper Arkansas (above Pueblo, Colorado)

Flood Control Survey investigations of the Upper Arkansas River Watershed in Colorado are an important part of the comprehensive survey now under way in the Arkansas-White-Red Basin. This assignment was one of the major jobs attacked during the year. Accomplishments include the following tasks:

1. A survey work outline was completed.

2. A preliminary survey of land ownership and plant cover.

3. Selection and field study of 14 sample watersheds to ascertain site characteristics, present condition, kinds and relative amounts of improvement measures needed, and probable response to restorative treatment.

4. Agreement with the Corps of Engineers on responsibility for the collection of flood damage data and joint use of information. Data collection assigned to this Station was completed.

5. A field survey of erosion and sediment production, made in cooperation with the Soil Conservation Service was completed.

6. Agreements were reached with field representatives of the Soil Conservation Service and the Bureau of Land Management on criteria to be used in analyzing and reporting cover and soil conditions and flood control needs on range lands of the watershed.

7. Participation in numerous meetings of the Colorado State AWR Committee and subcommittees assigned to specific phases of the comprehensive survey.

South Platte (Supplemental Report)

During the year the Department of Agriculture decided to prepare several reports on relatively small subwatersheds of the Missouri River Basin as supplements to the Comprehensive Agricultural Program report for that basin as proposed by the Public Work Committee of the House of Representatives. The South Platte Watershed above Kersey, Colorado, was selected as one of those for which a report would be prepared during the calendar year 1951.

A flood control survey of this watershed by this Station was in progress at the time the Comprehensive Missouri River Basin Survey was begun in 1948. This survey was essentially completed and the results were included in the Missouri River Basin report.

Information obtained in this earlier survey made it possible to complete a supplemental report on flood control phases with very little additional field work. However, a considerable amount of time was required in order to effect changes brought about by recently adopted revised procedures.

The job of preparing the supplemental comprehensive report was directed by a subcommittee of the Colorado State Mobilization Committee with representation from the Forest Service, Soil Conservation Service, Production and Marketing Administration, State Agricultural College, and the State of Colorado.

Some minor delays were encountered in reaching the uniform agreement on such things as kinds and amounts of measures needed, nomenclature to be used, unit costs, effect of going programs, and benefits to be derived from the programs, but in early December a draft of the supplemental report including the flood control phases was completed and submitted to the Missouri River Basin USDA Field Committee for final review and correlation with other similar reports.

Fountain Creek Watershed

During the early part of the year several minor revisions were made in the Fountain Creek report with respect to the evaluation of damages and benefits. The report was submitted to the office of the Secretary of Agriculture in midyear, after which further revisions were made to adjust values to an index of long-term projected prices. The report was approved by the Secretary in December, and forwarded by him to the Governor of the State of Colorado and to member agencies of the FIARBC for review and comment.

Sevier Lake Watershed

At the beginning of the year the Sevier Lake report was reviewed by the Washington office of the Corps of Engineers and several bureaus of the Department of Interior. As a result of questions raised by the Corps of Engineers, it was necessary for our Flood Control staff to amplify certain hydrologic aspects of the report. These amplifications were accepted by the reviewing agencies, and the report was submitted by the Secretary of Agriculture to the Bureau of the Budget in May.

Wasatch Front Watershed

Early in the year a preliminary field draft of the Wasatch Front report was completed and sent to the Washington office of the Forest Service, the regional office of the Soil Conservation Service, the state offices of the Production and Marketing Administration, and

Agricultural Extension Service, the field representative of the Secretary of Agriculture, and the field office of the member agencies of FIARBC. After reviews had been received, revisions were made to place the report in line with recent procedural policies concerning evaluation of damages and benefits and to reflect anticipated long-term projected prices. The survey report was approved by the Forest Serivce and the Soil Conservation Service, and transmitted to the Secretary of Agriculture in November.

Virgin River Watershed

The first field draft of the Virgin River report was prepared early in the year and forwarded to the Washington office of the Forest Service, the regional office of the Soil Conservation Service, and the regional representative of the Bureau of Agricultural Economics. Since that time certain revisions have been made in the report to place it in accord with changed economic procedures. As soon as all comments are received the report will be reproduced and circulated to field offices of member agencies of the FIARBC.

Boise River Watershed

The 1949 draft of the Boise River report brought out many different view points from the reviewing agencies. These pertain particularly to methods of hydrologic analysis, evaluation of sedimentation damages occurring to reservoirs and other irrigation works, and the manner in which benefits to be derived by the reduction of these damages should be measured. As a result it became necessary to effect major revisions in the report and to develop certain supplemental hydrologic analyses. To assist in this work a member of the Flood Control Survey staff was sent to Washington early in the year for an extended period. The evaluation procedures finally decided upon resulted in an unfavorable cost-benefit ratio for necessary flood control work in the mountainous part of the watershed. It was agreed, however, that the remedial measures needed in this part of the watershed would produce desirable benefits which could not be adequately evaluated by currently accepted procedure. The recognition of this fact has required further revision of the report to express the intangible and unevaluated benefits which will be derived from the program. After full consideration of needed revision a draft was agreed upon, and the report and appendix material were awaiting reproduction at the close of the year.

Cooperation with the Soil Conservation Service

Big Blue Watershed (Missouri River Basin Supplemental Report).--The decision in late summer by the Missouri River Basin USDA Field Committee to complete a supplemental report on the Big Blue Watershed in Nebraska and Kansas resulted in a request from the Soil Conservation Service for assistance on the farm, woodland, and other farm forestry problems and needed remedial program for that watershed. Twoomey of the Flood Control Survey staff, and Dunston of Region 2 of the Forest

Service were assigned to this study which required about 3 weeks of field work. After their review of available information of the farm forestry situation and needs, contacts were made with state and local representatives of the Soil Conservation Service and the Production and Marketing Administration, and with the Agricultural Colleges of Nebraska and Kansas. A report on the forestry phases of both the flood control and comprehensive program for this watershed was prepared and submitted to the regional office of the Soil Conservation Service which is charged with preparation of the preliminary draft of the report of this watershed. Late in the year a draft of the complete report for the flood control phases was received, reviewed, and returned with minor comment.

Middle Rio Grande Watershed.--During the forepart of the year the forestry phases of the survey report on this watershed were revised in order to adjust the estimates of conservation benefits anticipated from the recommended program as dictated by new information and recently announced procedural policies.

A preliminary draft of the survey report was received from the Soil Conservation Service in June of this year. Additional copies were submitted to the Washington office of the Forest Service, the Southwestern Forest and Range Experiment Station, and Region 3 of the Forest Service.

Numerous comments were submitted by the reviewing offices which, when added to those of our own staff, presented a rather difficult job of coordinating and clarifying all of the various comments. Forest Service comments were submitted to the Soil Conservation Service in October, and were incorporated in a revised draft of the report which was received in December. Field concurrence of the Forest Service was submitted to the Soil Conservation Service, on condition that a few changes be made in preparing the final field draft of the report.

LOCAL FLOODS

Local floods were investigated during the summer of 1951 in Colorado, Utah, and Idaho. Rainfall, runoff, and cover conditions, described more fully in memorandum reports, are summarized below:

Flood of August 2-3, 1951, near Fort Collins, Colorado.--A storm with two distinct periods struck the foothills between Boulder and Livermore with a center near Fort Collins totaling an estimated 12 inches of rainfall. The first period occurred on the evening of August 2 with 4 to 6 inches of rain in the mountains. During the second period on the evening of August 3 hourly amounts of 1.62 and 1.66 inches were recorded at Fort Collins and Boulder. A hydrograph from Buckhorn Creek showed that very little runoff resulted from the first period. The second period with a 5-inch average rain over 52 square miles of contributing area produced about 23 percent runoff and a peak flow of 14,500 cubic feet per second. Exceptionally heavy property damage occurred and several lives were lost.

About half of the contributing area is covered with dense ponderosa pine and Douglas-fir; the rest is covered with open ponderosa pine, brush, and grass of which about 60 percent is in poor condition. Runoff was negligible from the Douglas-fir type. There was evidence of large amounts of runoff and erosion from the ponderosa pine grasslands in poor condition. Some runoff occurred but there was little indication of erosion from ponderosa pine-grasslands in good condition.

Flood of August 3 near Alpine, Utah.--A general storm struck the Wasatch Mountains from Provo to Willard on August 3 and 4. The total rainfall recorded broke all previous records for July and August in the Salt Lake Valley. Gages in the vicinity of Alpine, Utah, caught about 1.5 inches on August 3 and it appears that rainfall at higher elevations was much heavier. In this vicinity, damaging floods and debris discharges issued from several mountain watersheds. The floodwaters and debris came from various combinations of steep, rocky slopes and depleted grass lands at high elevations.

The principal source of runoff from Box Elder Canyon was the zone between 9,000 and 11,000 feet in elevation where there is about 40 acres of exposed bedrock, but 300 acres of forested land in the upper portion of this basin generally provided adequate protection as did the brush cover at lower elevations. Most of the debris came from the head of a raw channel ripped out by earlier floods.

Most of the floodwater and debris discharged from Deer Creek came from a tributary (Wide Hollow) which contains about 150 acres of disintegrating talus slopes and 250 acres of depleted range lands above 9,000 feet. The bulk of the flood runoff and debris came from these steep, rocky slopes and from the main channel.

Flood of July 27, 1951, near Rockland, Idaho.--On July 27, 1951, a local thunderstorm struck about 25 square miles of dry farmland along a 5-mile stretch between Rockland and Roy, Idaho. About half of the area was summer-fallowed and the finely pulverized surface produced most of the sediment which was removed to plow-sole depth on steep slopes. Areas occupied by native vegetation showed little erosion; grain crops prevented severe erosion on other lands. It was roughly estimated that many fallow fields lost 20 percent of their topsoil.

COLORADO RIVER BASIN

The urgency of assignments on other watersheds, especially those involving comprehensive river basin planning, left little time during the year for work on the Colorado River Basin. Nevertheless, the first draft of the Flood Control Survey problem analysis for this basin was completed by a committee and is awaiting review by other staff members.

A report was completed by Croft and Adams on their joint study of erosion conditions on the San Rafael Watershed. A summary of this report was presented at the December meeting of the PSFIATC.

The extent of Congressional authority for flood control surveys in the Colorado River Basin was investigated and several conferences were held with Warren Murphy, Special Field Representative of the Secretary of Agriculture, regarding action needed to obtain necessary additional survey authorization.

Compilation and drafting of base maps for major subdivisions of the basin was continued as permitted by other higher priority tasks. Review and analysis of all infiltration tests which have been made under conditions similar to those encountered in the Colorado Basin was started.

OTHER ACTIVITIES

In addition to work assignments connected with survey activities on specific watersheds other tasks of more general nature required considerable time. The most important of these include the following:

1. Assistance in revising Project Work Inventories on all national forests in Region 4.

2. Participation in the informational training of foreign visitors under the auspices of the ECA program. Similar aid was given to a group of Japanese Government officials and technicians who visited the Station in early summer.

3. Completion of several infiltration tests on the Uinta National Forest to obtain factual information needed by the Region in planning necessary adjustments of livestock grazing use. Field tests, which were limited by lateness of the season, were supplemented by laboratory study of soils and sediment and by the analysis of results.

4. Work by staff members on manuscripts for prospective publications. These include: "Water Yield in Relation to Use on Small Watersheds," "Runoff Trends in the Sevier Watershed," and "Observations of Infiltration and Erosion Characteristics on Browse-Shrub Cover in the Intermountain West" by Rosa and Tigerman, "Erosion Characteristics of the San Rafael Watershed" by Adams and Croft, and "The Soil Profile as an Aid to Range Management" by Olson.

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STATION PERSONNEL, C.Y. 1951

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